6.0 IMPACTS PROJECTED BY THE MODEL UNDER ALTERNATIVE 1 (PROPOSED ACTION)

The primary effects of CBM development on groundwater resources are associated with the removal of groundwater stored within coal seams and the subsequent recharge of aquifers through infiltration or injection of produced water. The primary purpose of the numerical flow modeling was to project impacts to groundwater from CBM development in the PRB. The model also included the superimposed influences of surface coal mining operations. Modeling was necessary because of the large extent and variability of the cumulative stresses imposed by mining and CBM development on the aquifer units of the PRB. Modeling a hydrologic system on a regional, basin-wide scale allows a comparison of alternatives and a determination of the mass water balance so that long-term gain or loss can be forecast. The regional model is an adequate tool for analyzing the effects of CBM development, but the results should be used with caution when a sub-regional or local area is considered. The regional model is constructed using averaged and smoothed values so that localized conditions are typically not highly defined.

The effects of groundwater extraction during CBM development on groundwater resources would be seen as a drop in the water level (potentiometric drawdown) in nearby water wells completed in the developed coals of the upper portion of the Fort Union Formation and underlying or overlying sandstone aquifers. Drawdown is observed when a loss in hydraulic pressure head occurs in the developed coals or in the overlying and underlying sand aquifers. Other potential effects on existing water wells include changes in water yield, quality, or methane emissions. Potentiometric drawdown may also change the nature of groundwater discharge to the surface in the form of reduced spring flows, seeps, or base flows to surface drainages.

Surface discharge of extracted groundwater from CBM operations into surface drainages, flow-through stock reservoirs, or infiltration impoundments would enhance recharge of shallow aquifers below creeks and impoundments. Injection of CBM-produced water would recharge the aquifer units in whichthe injection wells are completed.

6.1 Water Yield (CBM-Produced Water)

Table 6-1 shows the quantity of water projected by the model that would be removed during CBM development from 2002 through 2017. The projected discharge is summarized by sub-watershed. The Salt Creek sub-watershed is in a boundary area of the model that does not remain saturated for the transient simulation and therefore showed extremely low production volumes. Water removal (modeled) is projected to peak during 2007 at a rate 277,000 acre-feet per year (2,148,600 thousand barrels [Mbbls] per year).

CBM produced water is derived primarily from storage within the developed coals and leakage of groundwater contained in sand units into the coals as a result of coal depressurization. Over the life of a CBM well, most of the produced water may come from leakage into the coal from above and below. Storage in the coal is removed early in the life of a CBM well.

An example illustrates this concept and explains declines in production that are typically seen in the PRB. Consider a 50-foot thick coal seam at a depth of 1,000 feet that is bounded above and below by 40-foot thick claystones that separate the coal from overlying and underlying sandstone units. Assume that CBM development is occurring on an 80-acre well spacing and depressurization of the coal causes an average drop in potentiometric head of 500 feet.

If the coal is not dewatered (in other words, water is removed from confined storage only by depressurization), then the contribution of the coal to well water production depends on the drop in head and the confined storativity. Using a typical storativity for the coal of $5x10^{-6}$ ft^{-1}, the confined storage contribution from the coal would be about 2 acre-feet for every 100 feet of head drop, or 10 acre-feet in this example.Additional water in unconfined storage would be released to the well if the coal were completely dewatered. The unconfined storage in the coal depends on the thickness of the coal and the specific yield. Assuming a specific yield for the coal of 0.4 percent (Section 2.3.3), the amount of unconfined storage in the coal in the 80-acre-feet area of one production well would be 16 acre-feet. The contribution from confined storage therefore becomes comparable with the contribution from unconfined storage in the deeper parts of the basin where drops in head of between 500 to 1,000 feet may be encountered. The total volume of storage in coal (from confined and unconfined storage) of 26 acre-feet (about 8.5 million gallons) is equivalent to a well pumping at 10 gpm for 1.6 years.

Removal of water from storage in coal is concurrent with leakage into the coal from above and below so, depending on the rate of leakage, the coal does not necessarily become dewatered in the short time frames noted above. The contribution from leakage would increase over the life of a well as water stored in the coal is removed. Leakage rates under high induced vertical gradients can be significant. For this example, a 500-foot drop in head would result in a vertical hydraulic gradient across the claystones of 12.5 feet per foot. Assuming a very low vertical hydraulic conductivity for the claystone confining units of $6x10^{-11}$ ft/sec (derived from field data for the Marquiss area) results in a vertical leakage over the 80-acre area of 1.2 gpm from both above and below (for a total of 2.4 gpm). Higher drops in head, higher vertical hydraulic conductivities, or thinner claystone units would lead to higher leakage rates. The leakage rates for this example are typical of the pumping rates for CBM wells during the latter portions of their productive life.

The example above illustrates that most of the water produced by a CBM well likely would come from leakage after about the first 2 years of pumping,. The higher storativity and specific yields in the sandstones result in relatively less observable drawdown in these units compared with the coal (as actually observed in nested monitoring wells) while still providing a large source of water for leakage into the coal.

A review of Table 2-4 indicates that the majority of recoverable groundwater in the PRB is contained in the sandstones of the Fort Union and Wasatch Formations. The total projected CBM water production from 2002 to 2017 shown in Table 6-1 (about 2.93 million acre-feet) exceeds the estimated recoverable water within the coal units of the Wasatch and Fort Union Formations, but is less than 1 percent of the total recoverable groundwater (about 745.6 million acre-feet) in these formations.

Depending on the water handling practices used within each sub-watershed under Alternative 1, an estimated 15 to 33 percent of the pumped water would be recharged to the groundwater system as a result of infiltration along creeks and below impoundments (Table 3-1). Table 4-3 summarizes assumptions for groundwater and the fate of the CBM-produced water under Alternative 1.

Table 6-1
Regional Model Projection of Water Production from CBM Wells under Alternatives 1, 2A, and 2B
(Average volume of water produced from CBM development [in 1,000 barrels])

Sub-watershed	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	TOTAL
Upper Tongue River	49,900	70,900	95,600	110,400	118,800	126,900	129,900	140,800	140,200	135,400	120,000	107,800	84,200	65,900	44,800	23,900	1,565,400
Upper Powder River	573,000	774,300	922,900	1,022,900	1,100,200	1,140,600	1,134,100	1,015,400	899,400	776,500	643,800	492,500	309,900	140,000	75,300	28,900	11,049,700
Salt Creek	29	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54
Crazy Woman Creek	47,800	83,900	111,500	133,200	147,900	161,400	168,700	150,900	131,400	116,900	95,000	76,700	56,400	36,000	23,800	12,700	1,554,200
Clear Creek	46,200	73,500	99,900	126,500	150,100	170,000	177,000	179,400	177,400	175,500	150,200	125,800	99,400	76,400	52,700	28,000	1,908,000
Middle Powder River[1]	53,300	56,600	59,700	62,100	60,600	51,800	40,700	45,100	46,300	47,000	42,700	37,600	31,600	25,300	18,300	9,000	687,700
Little Powder River	125,000	123,700	120,700	122,800	111,500	101,200	77,300	78,900	81,000	81,000	70,800	62,500	50,000	38,500	26,100	15,100	1,286,100
Antelope Creek	54,400	61,100	70,400	75,600	81,400	83,000	82,000	77,400	74,200	68,700	60,800	51,900	39,400	25,400	18,700	11,100	935,500
Upper Cheyenne River	39,200	36,500	34,100	30,800	28,700	24,300	24,000	22,100	19,500	16,400	15,400	8,800	5,500	100	0	0	305,400
Upper Belle Fourche River	349,400	336,500	324,400	318,200	312,600	289,400	242,700	231,400	218,500	209,100	188,600	163,100	130,900	70,800	53,600	36,900	3,476,100
TOTAL	1,338,200	1,617,000	1,839,200	2,002,500	2,111,800	2,148,600	2,076,400	1,941,400	1,787,900	1,626,500	1,387,300	1,126,700	807,300	478,400	313,300	165,600	22,768,100

Note: Volumes shown include produced water from pre-2002 wells, as well as new CBM wells.
Assumes all pre-2002 wells have their first year of water production prior to 2002, and water production for the last pre-2002 wells ends after 2007.
Sub-watersheds where no new CBM development is proposed are excluded.

6.2 Projection of of Changes in Water Level for Upper Fort Union Formation

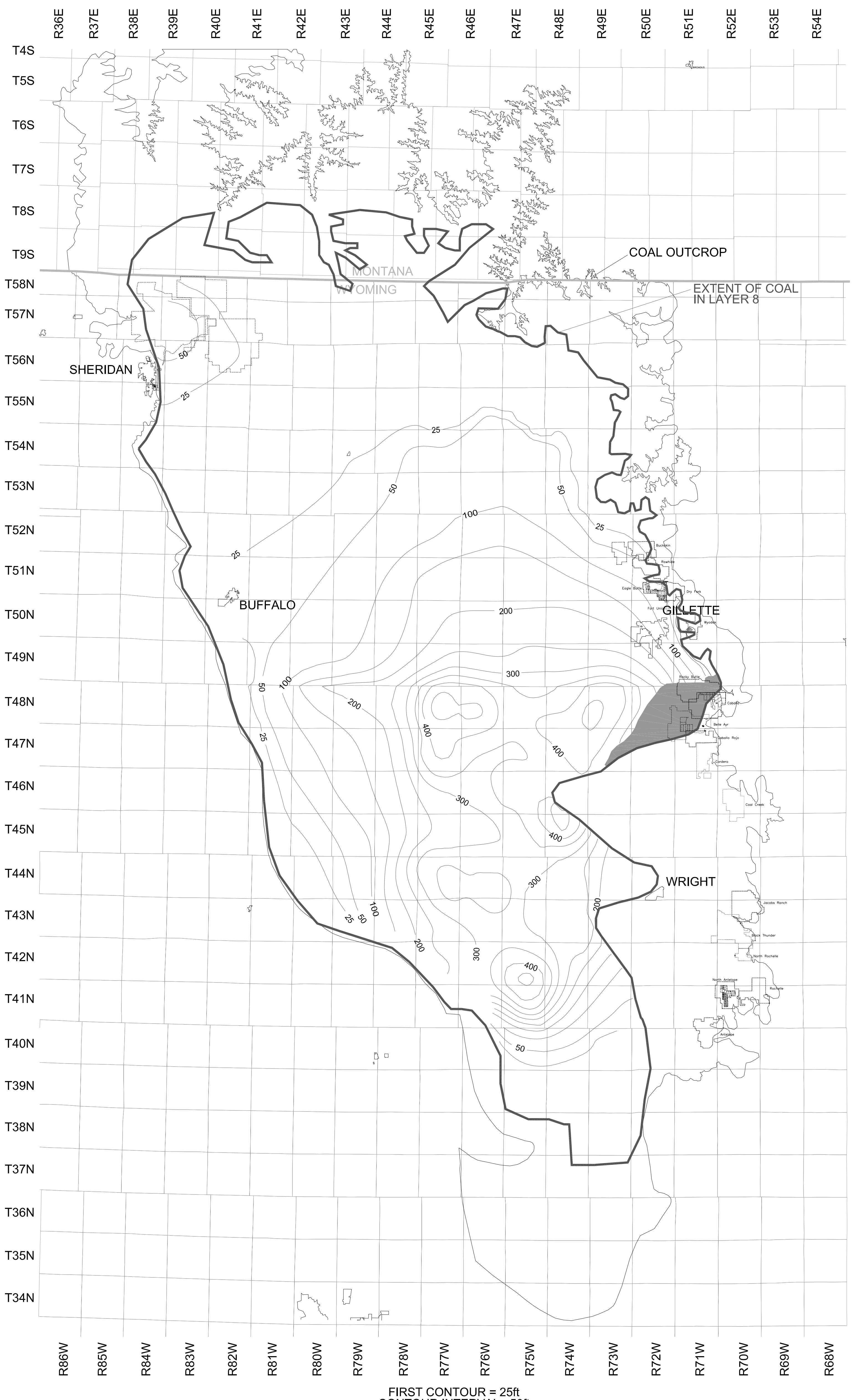
The ability of the model to reasonably project the extent and magnitude of changes in water level caused by coal mining and CBM development may be judged by comparing results projected by the model with actual trends in water levels. As described in Section 5.1.2, drawdown projected by the model for the year 2000 compares favorably with actual drawdowns where they have been measured (Figures 5-4 and 2-4). Drawdown projected by the model versus time compares well with actual drawdown measured at several monitoring wells with monitoring histories of several years (Figure 5-8 through 5-11). These results lend credibility to the model's projections of future changes in water level under the superimposed stresses of coal mining and CBM development.

6.2.1 Drawdown

Under Alternative 1, the model-projected drawdowns in the model layers representing the coal-bearing units of the upper portion of the Fort Union Formation are shown in a series of maps for the model years 2003, 2006, 2009, 2012, 2015, and 2018 (Figures 6-1A, B, C, and D through 6-6A, B, C, and D). The series of maps shows how the extent and magnitude of drawdown in the upper portion of the Fort Union Formation changes over time as CBM development spreads through the PRB. Because the mining and CBM operations are dynamic, the maximum areal extent of drawdown changes over time and may increase in some areas of the PRB while it recovers in others. Total CBM water production projected by the model in the Project Area under Alternative 1 peaks in year 2007 (Table 6-1). Peak production in the individual watersheds varies from 2002 to 2009 in the model, resulting in maximum drawdowns in these areas that occur at different times. The maximum drawdown in a sub-watershed generally coincides or closely follows the period of peak water production. The maximum drawdown projected by the model in the central area of the PRB, where the Big George coal would be developed, is projected to occur around 2009 under Alternative 1.

Maximum drawdowns occur in the vicinity of active mining operations and in the centers of CBM development. Because the numerical model is subdivided into discrete cells and CBM water production is simulated using drain nodes, the drawdowns caused by CBM well pumping are averaged over the area of a cell (about 160 acres). Consequently, model simulations are representative for areas located more than 200 to 300 feet from a pumping well. The drawdown at a pumping well would be more than is represented by the model. Maximum model-projected drawdowns exceed 700 feet in the deeper parts of the basin, such as in the northwestern portion. In shallower areas of the basin, such as the southeastern portion of the Project Area, modeled drawdowns would be 200 to 400 feet over most of the active CBM well fields.

Projections of maximum drawdown and the extent of drawdown are based on the projected locations of CBM development. Actual drilling locations and density of drilling may result in shifts of drawdown contours from the projections illustrated in Figures 6-1A, B, C, and D through 6-6A, B, C, and D.



LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 8
- Dry Cell
- Towns
- Mine Boundary

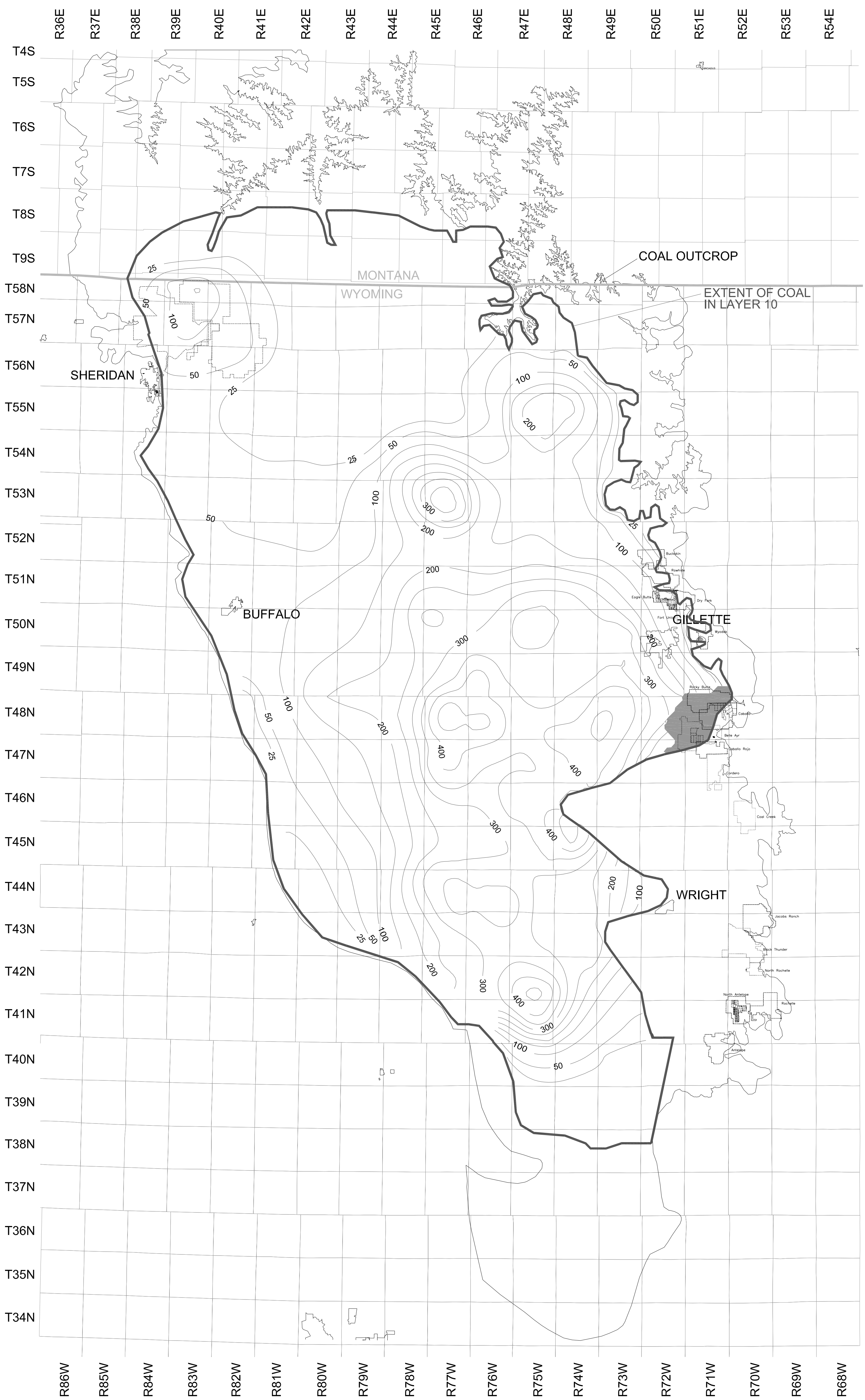
Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-1A MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 8 YEAR 2003	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-1 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-1A continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 10
- Dry Cell
- Towns
- Mine Boundary

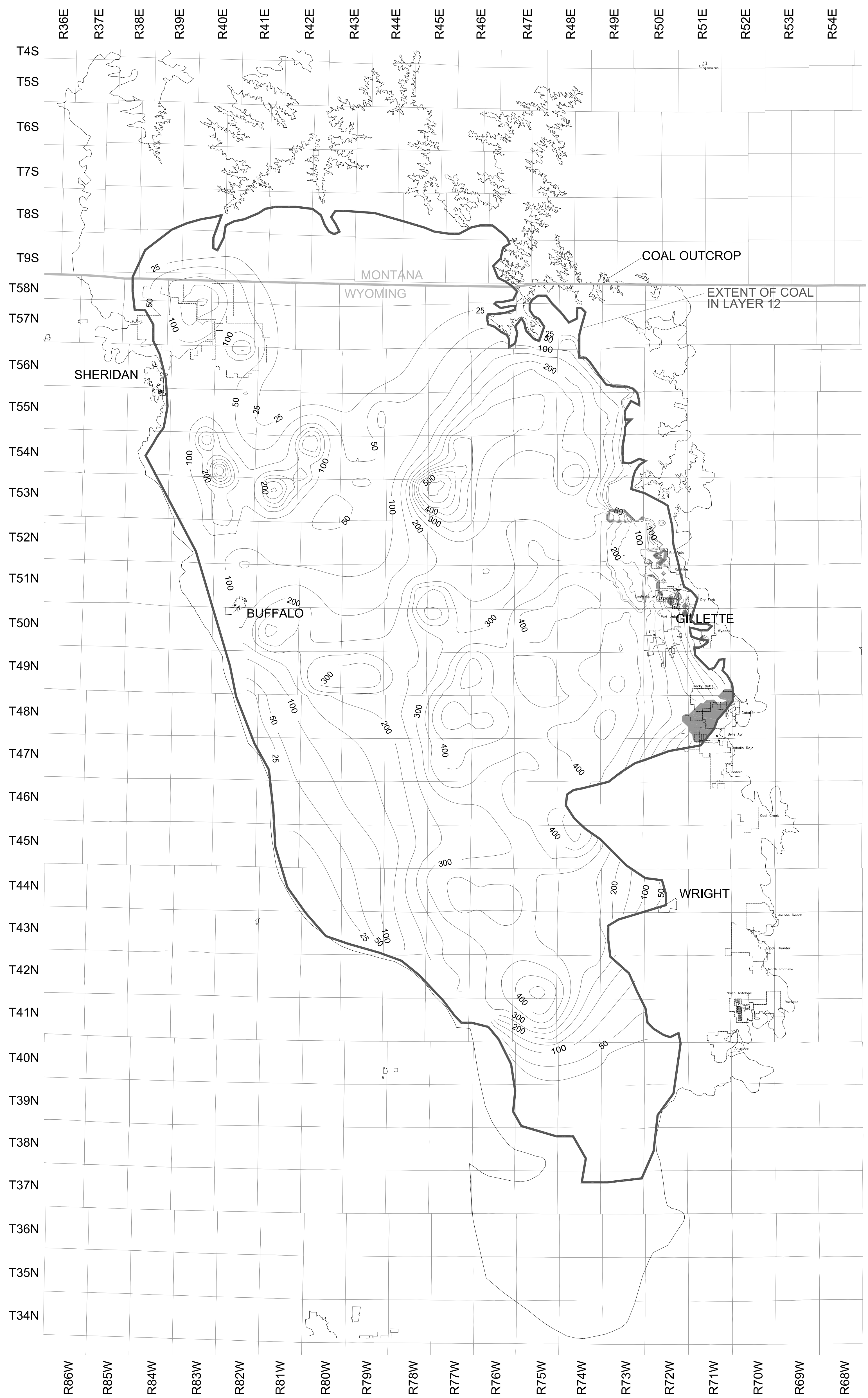
Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-1B MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2003	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-1 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-1B continued (11x17)



LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 12
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

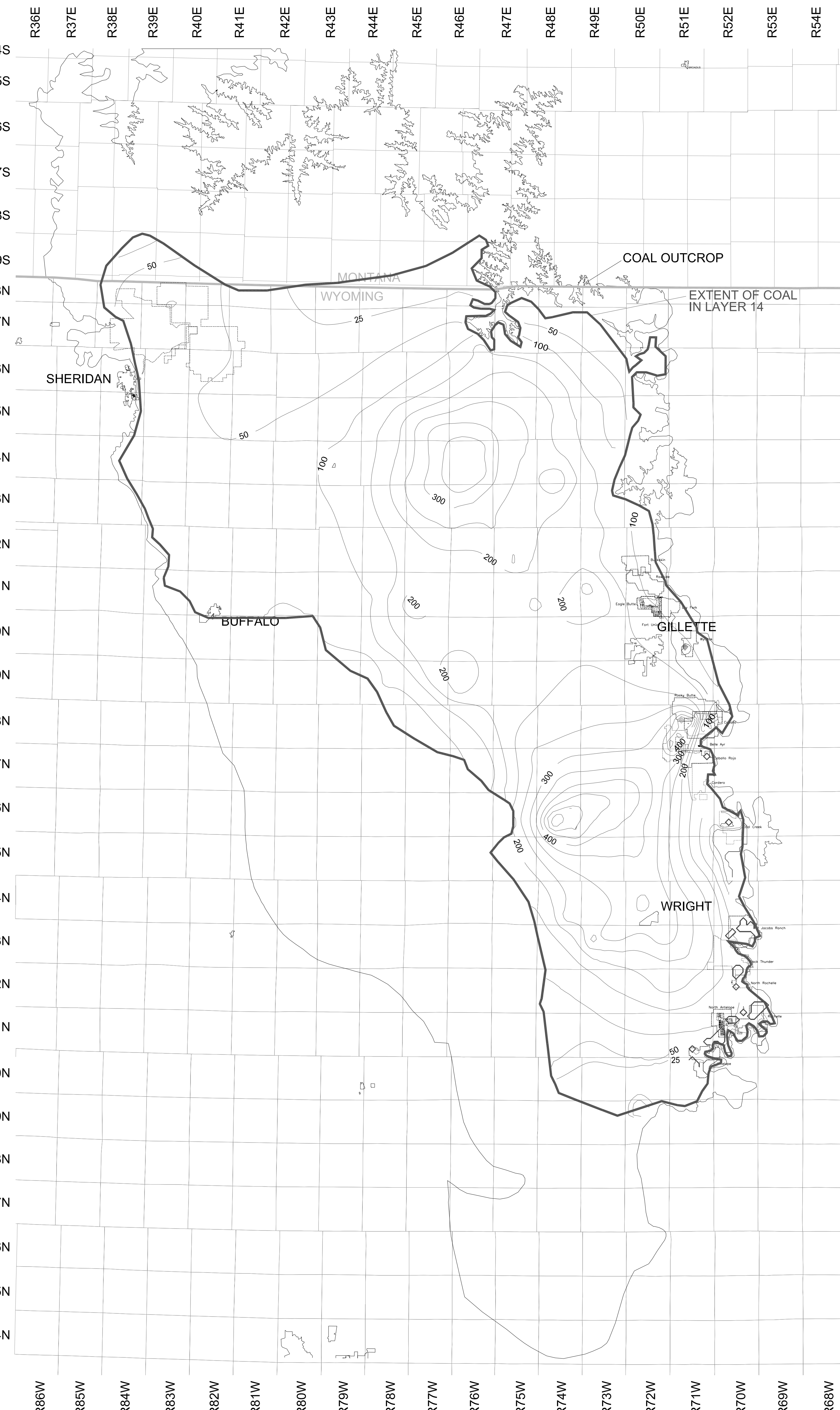
TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-1C
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2003

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-1 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-1C continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 14
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

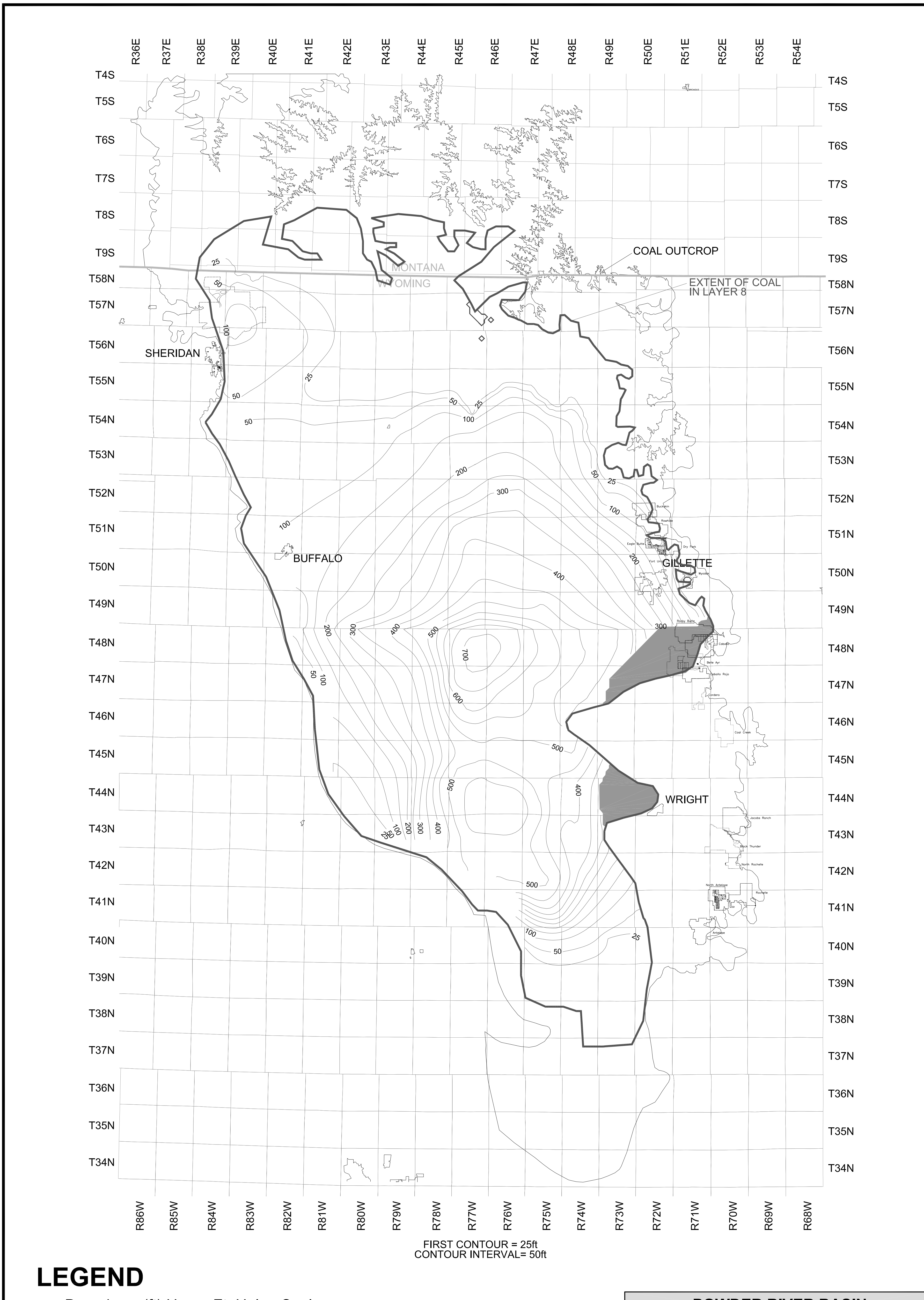
TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-1D
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 14 YEAR 2003

MODEL RUN: From 1999-2200 (08-26-02)

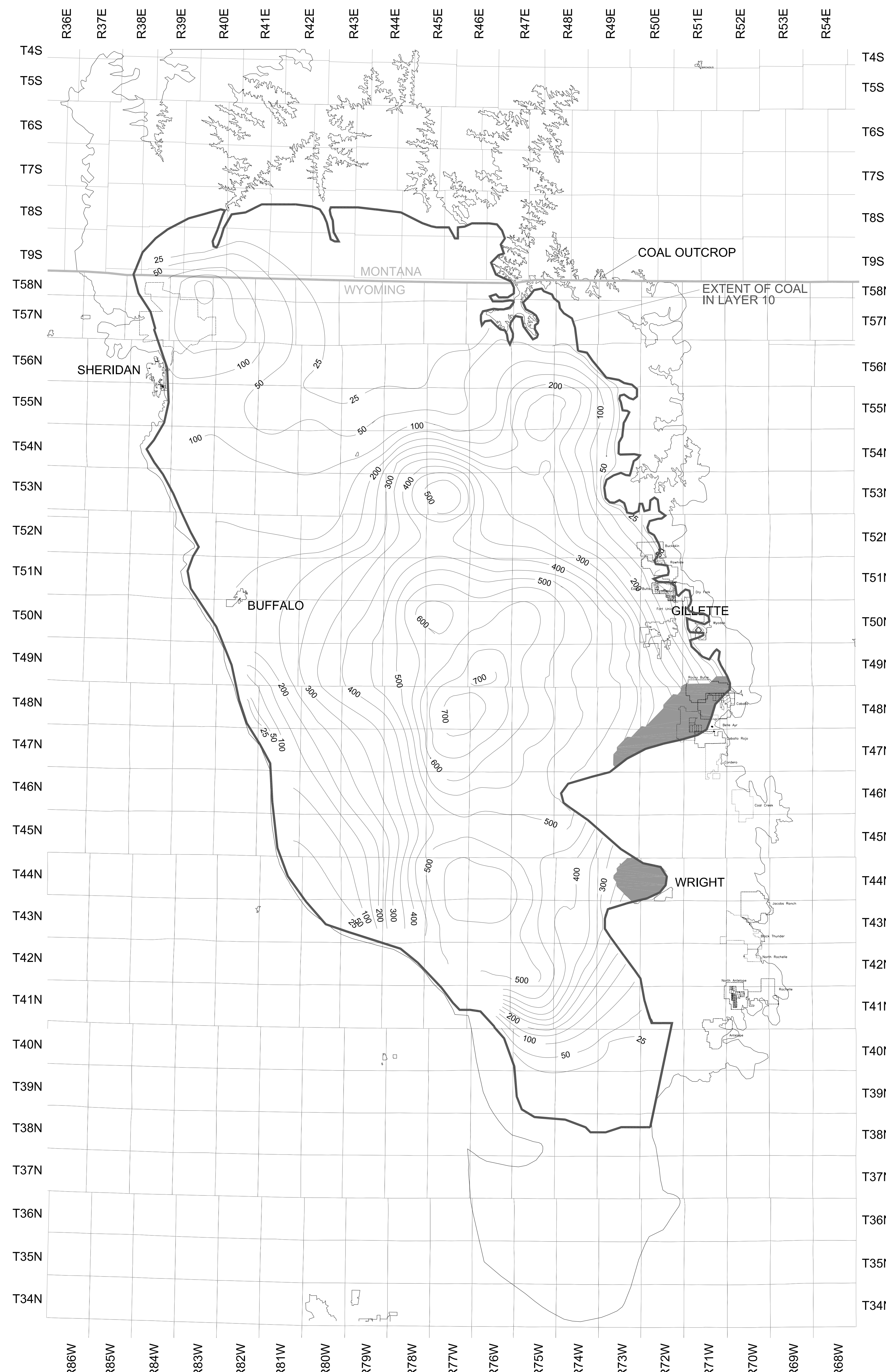
Date: 09/05/02	Drawing File: Figure 6-1 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-1D continued (11x17)



POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-2A MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 8 YEAR 2006	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-2 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-2A continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 10
- Dry Cell
- Towns
- Mine Boundary

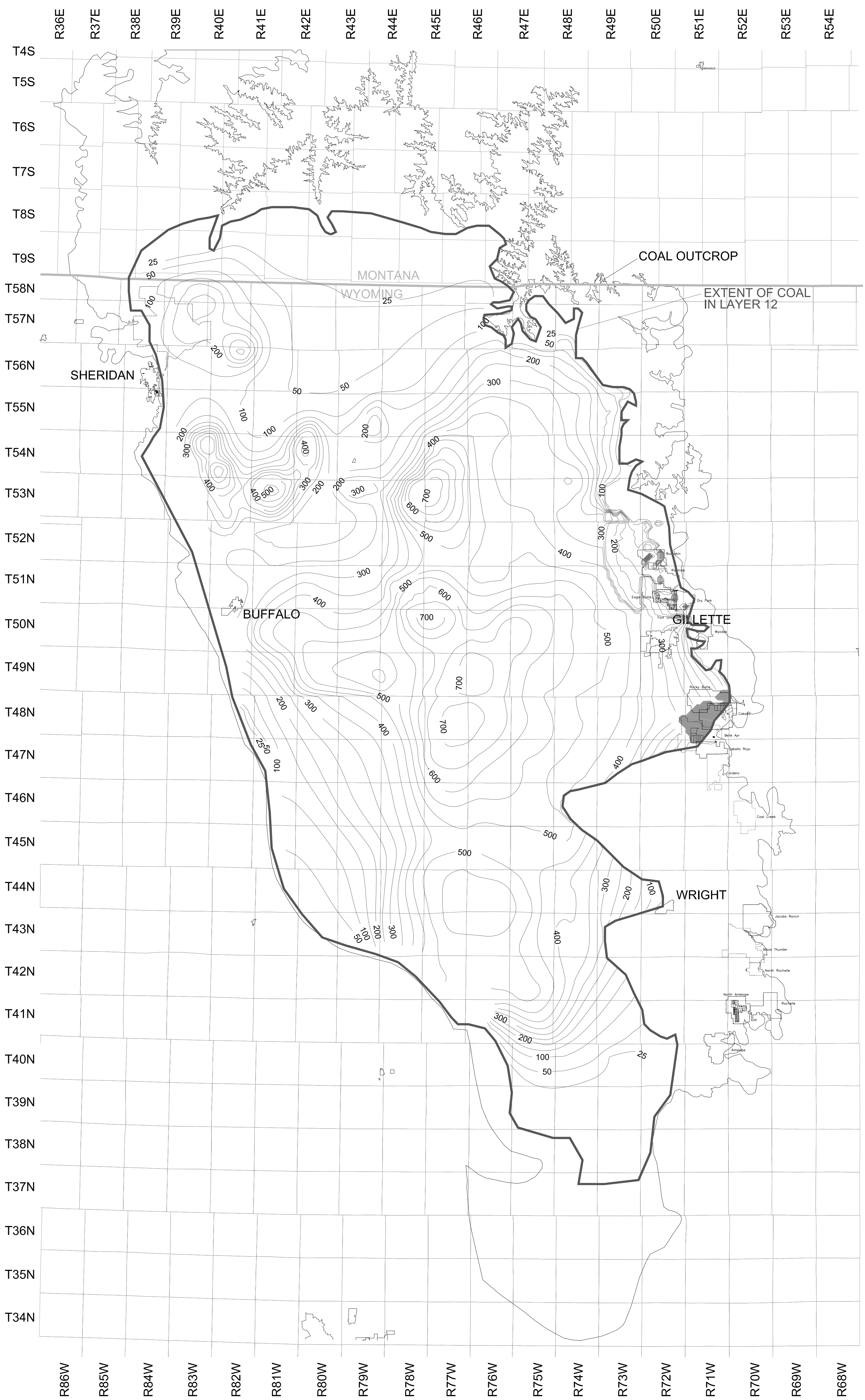
Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-2B MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2006	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-2 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-2B continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 12
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

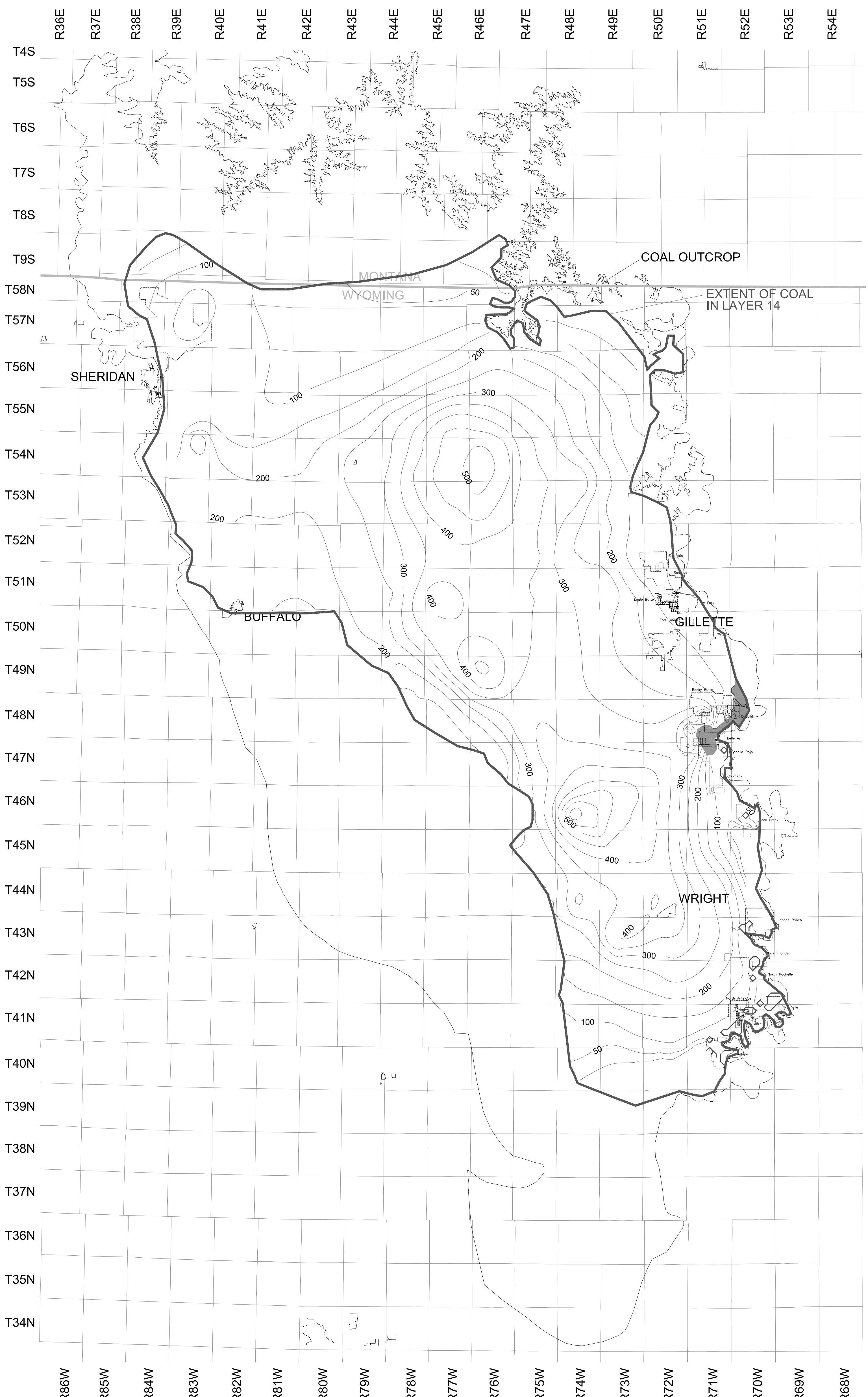
TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-2C
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2006

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-2 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-2C continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

Drawdown (ft) Upper Ft. Union Coals

Extent of Coal in Layer 14

Dry Cell

Towns

Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

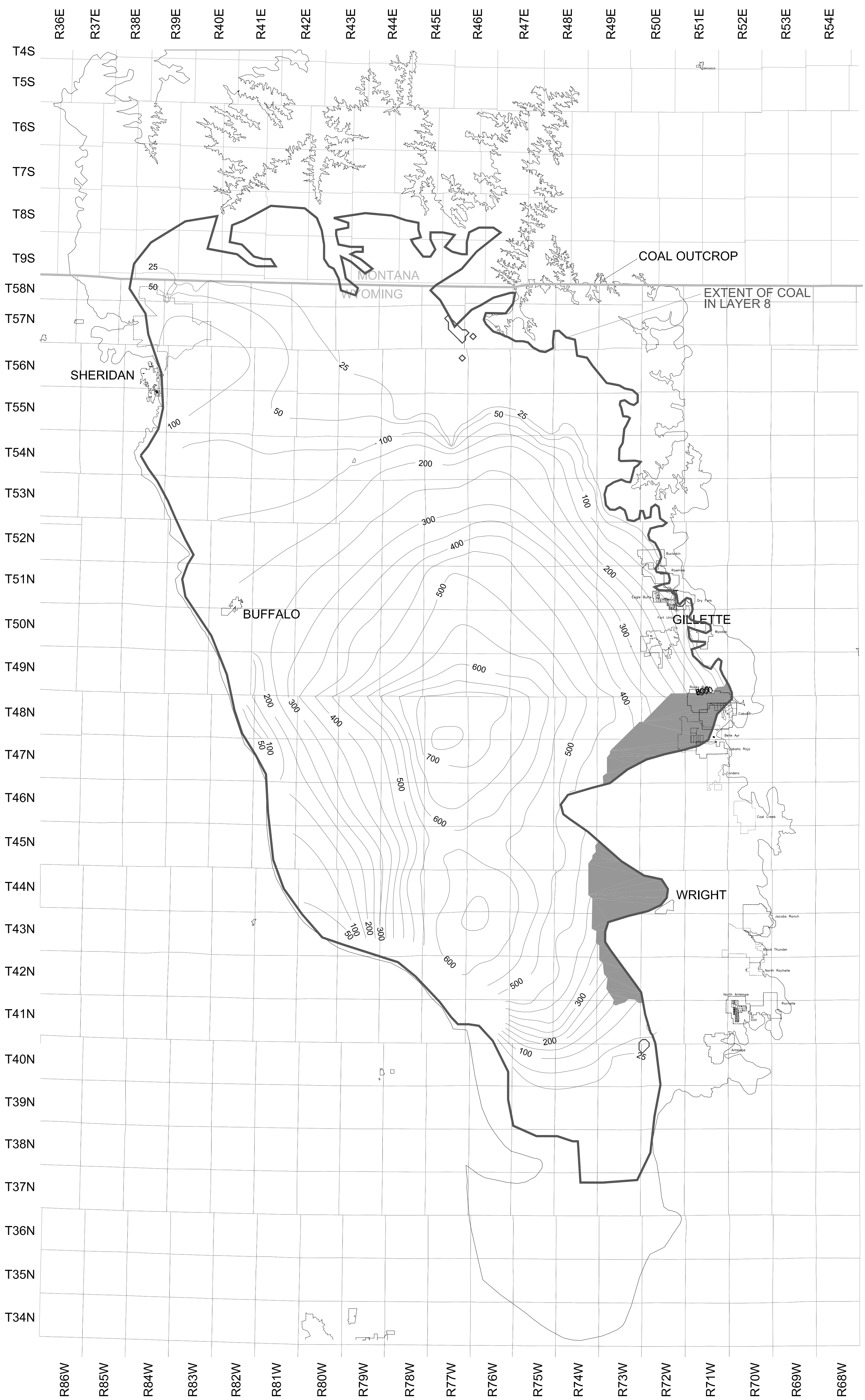
TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-2D
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 14 YEAR 2006

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-2 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-2D continued (11x17)



LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 8
- Dry Cell
- Towns
- Mine Boundary

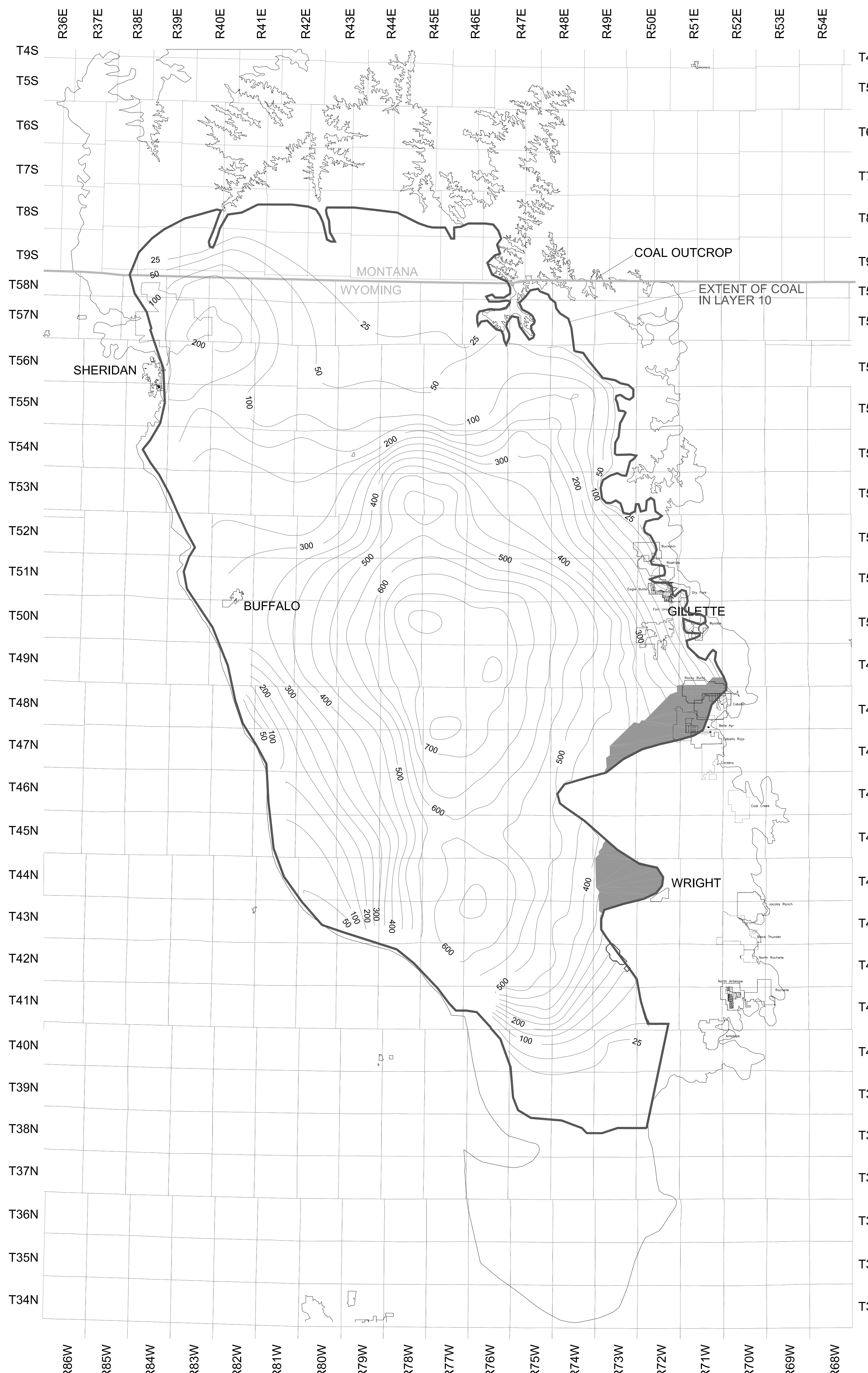
Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-3A MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 8 YEAR 2009	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-3 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-3A continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 10
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

0 7.5 15 30 Miles

N

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

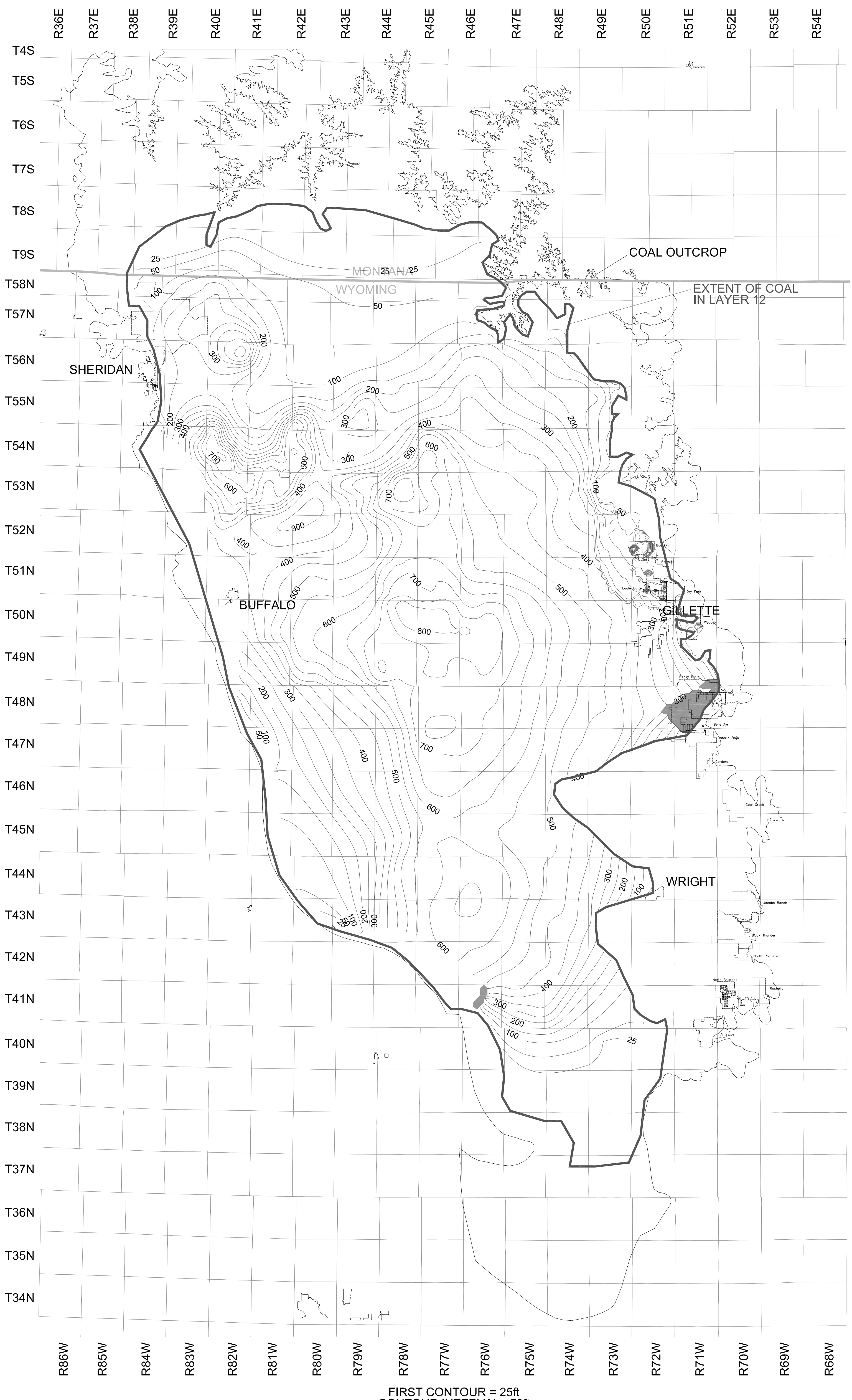
TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-3B
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2009

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-3 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-3B continued (11x17)



LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 12
- Dry Cell
- Towns
- Mine Boundary

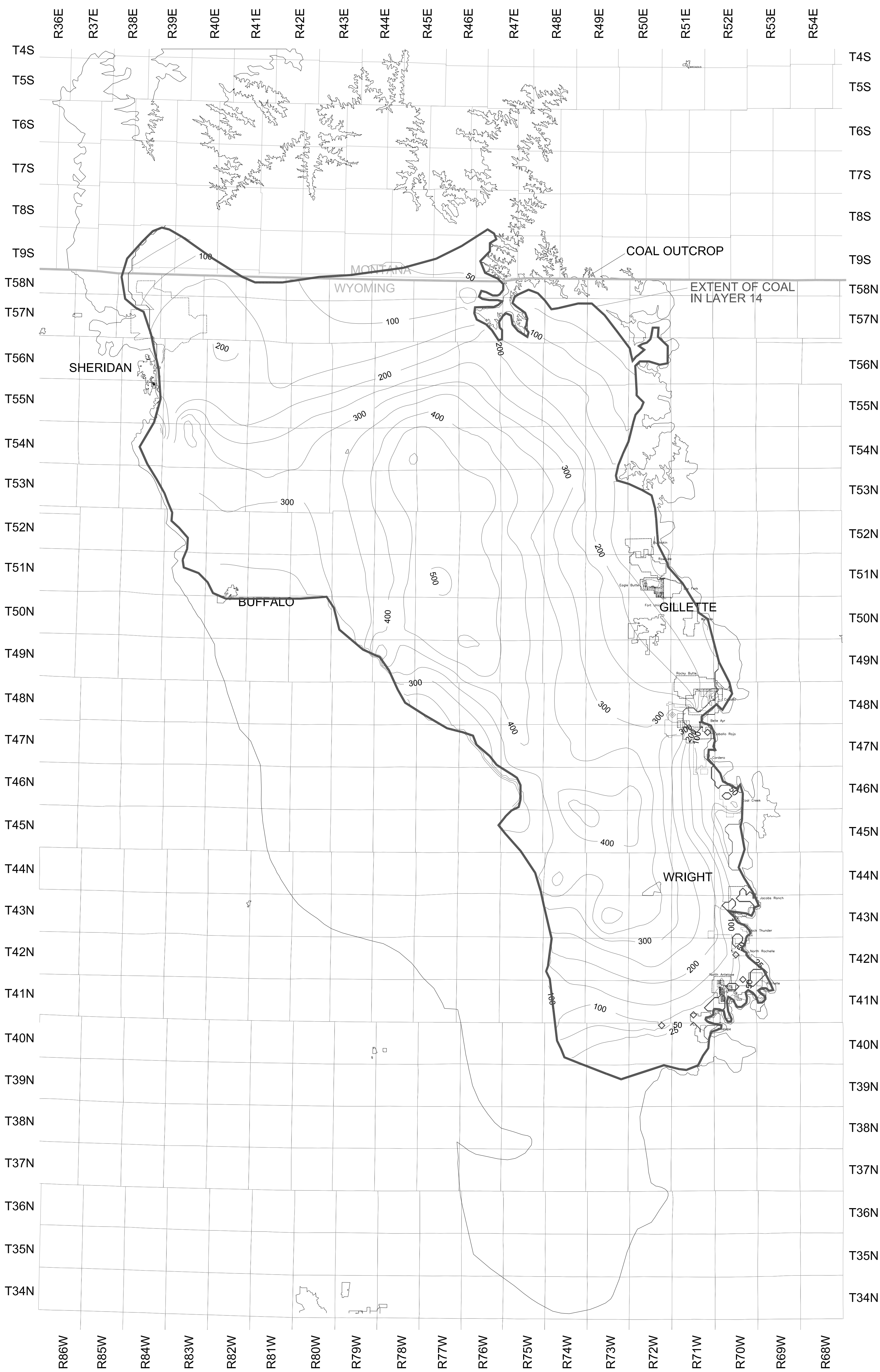
Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-3C MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2009	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-3 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-3C continued (11x17)

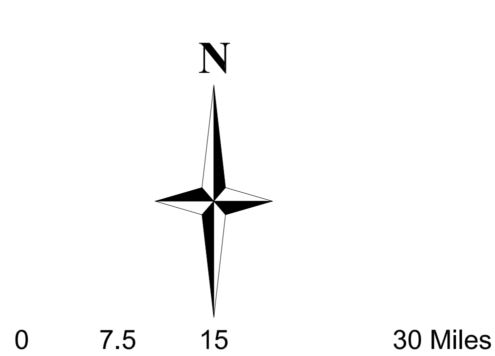


FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

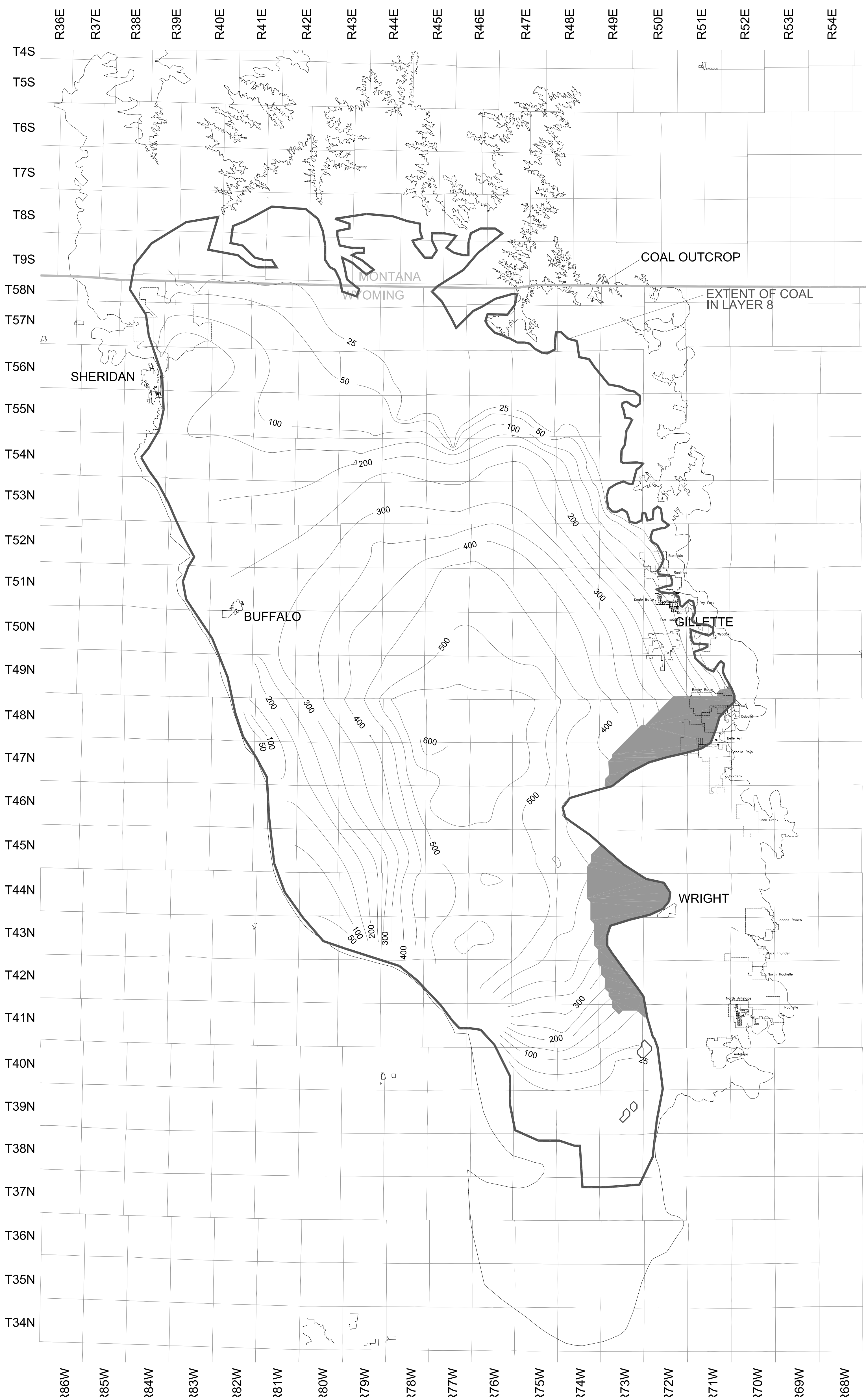
- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 14
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.



POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-3D MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 14 YEAR 2009	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-3 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-3D continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 8
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

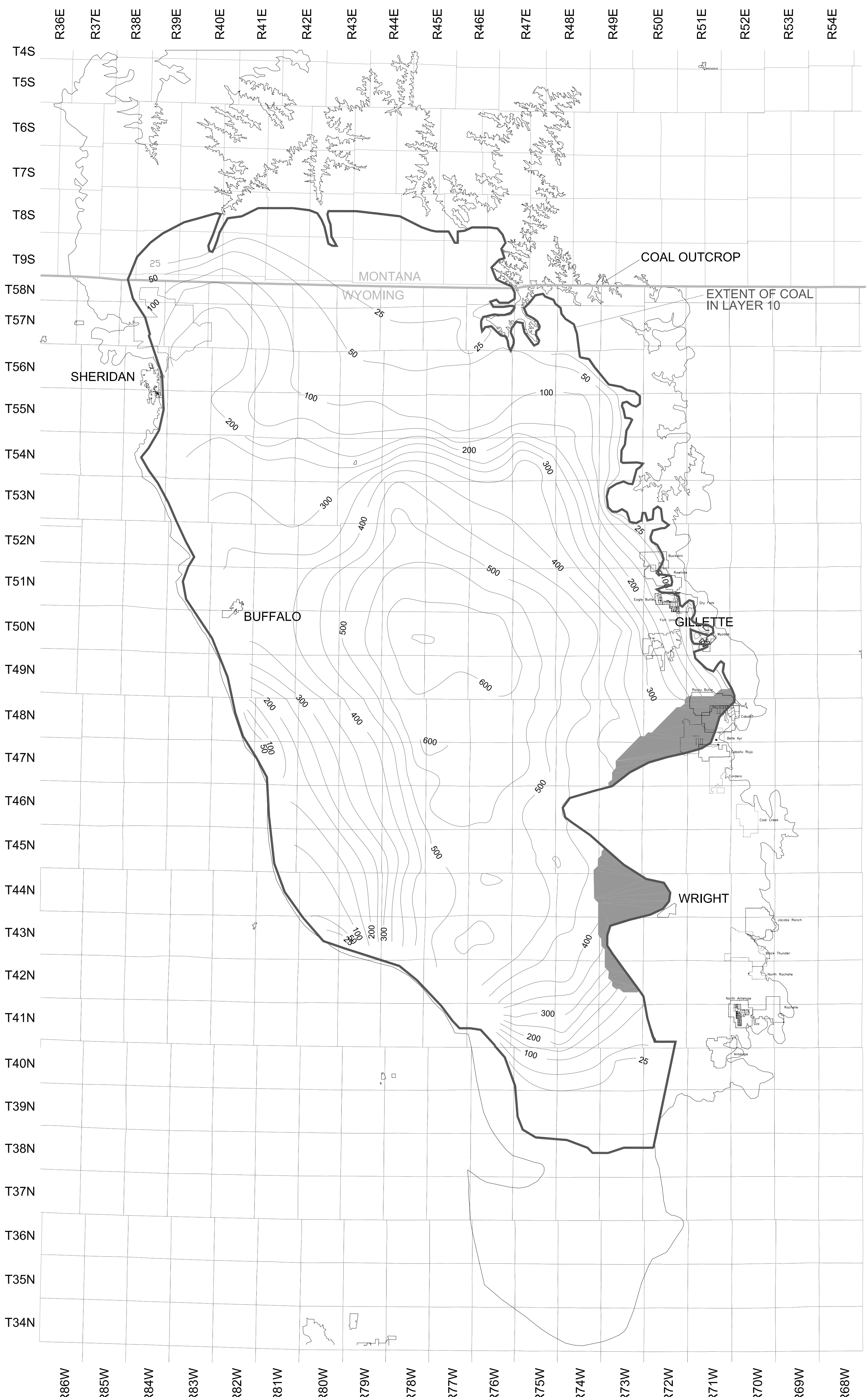
TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-4A
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 8 YEAR 2012

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-4 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-4A continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 10
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

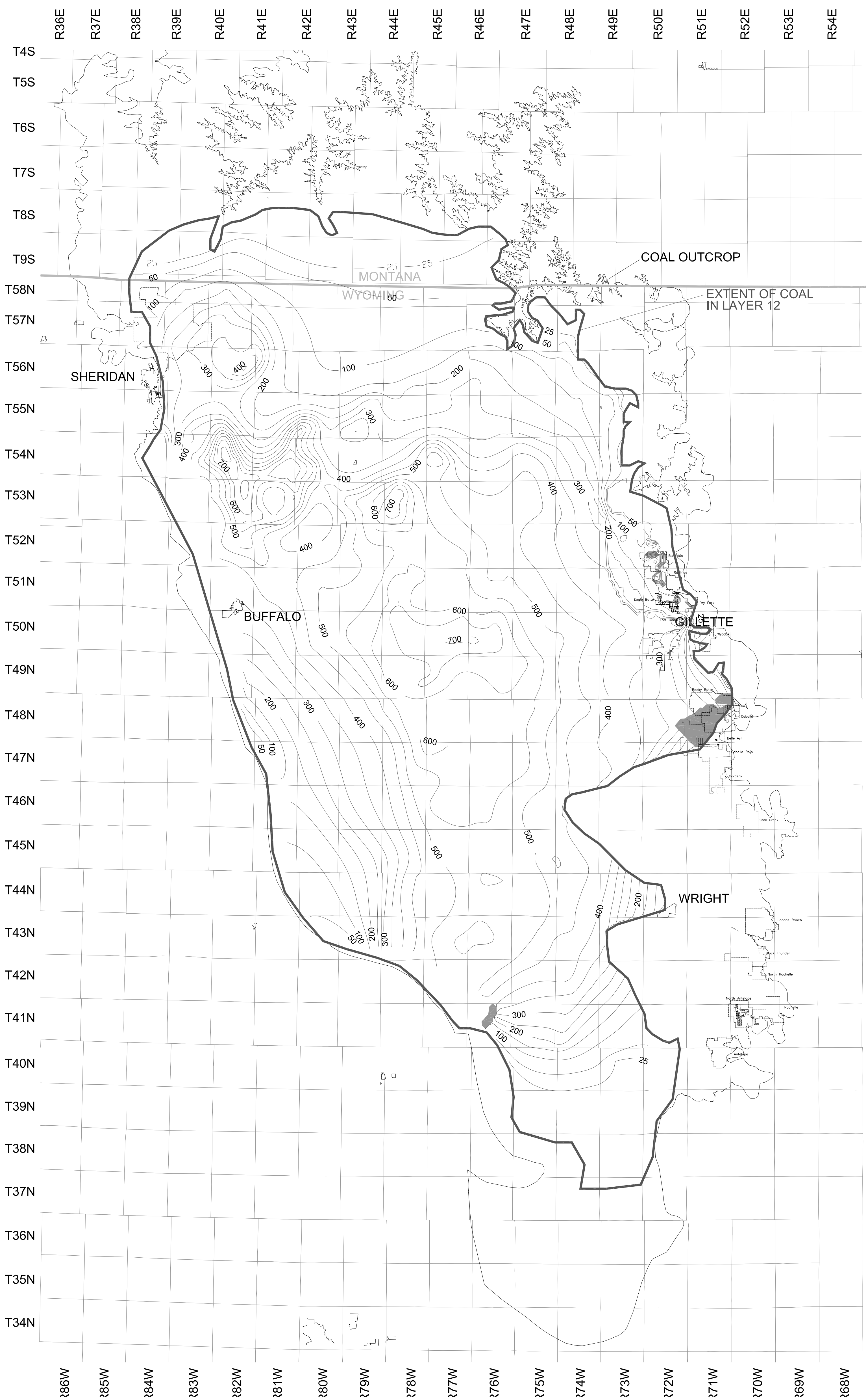
POWDER RIVER BASIN OIL & GAS PROJECT FEIS

TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-4B
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2012

MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-4 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-4B continued (11x17)



LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 12
- Dry Cell
- Towns
- Mine Boundary

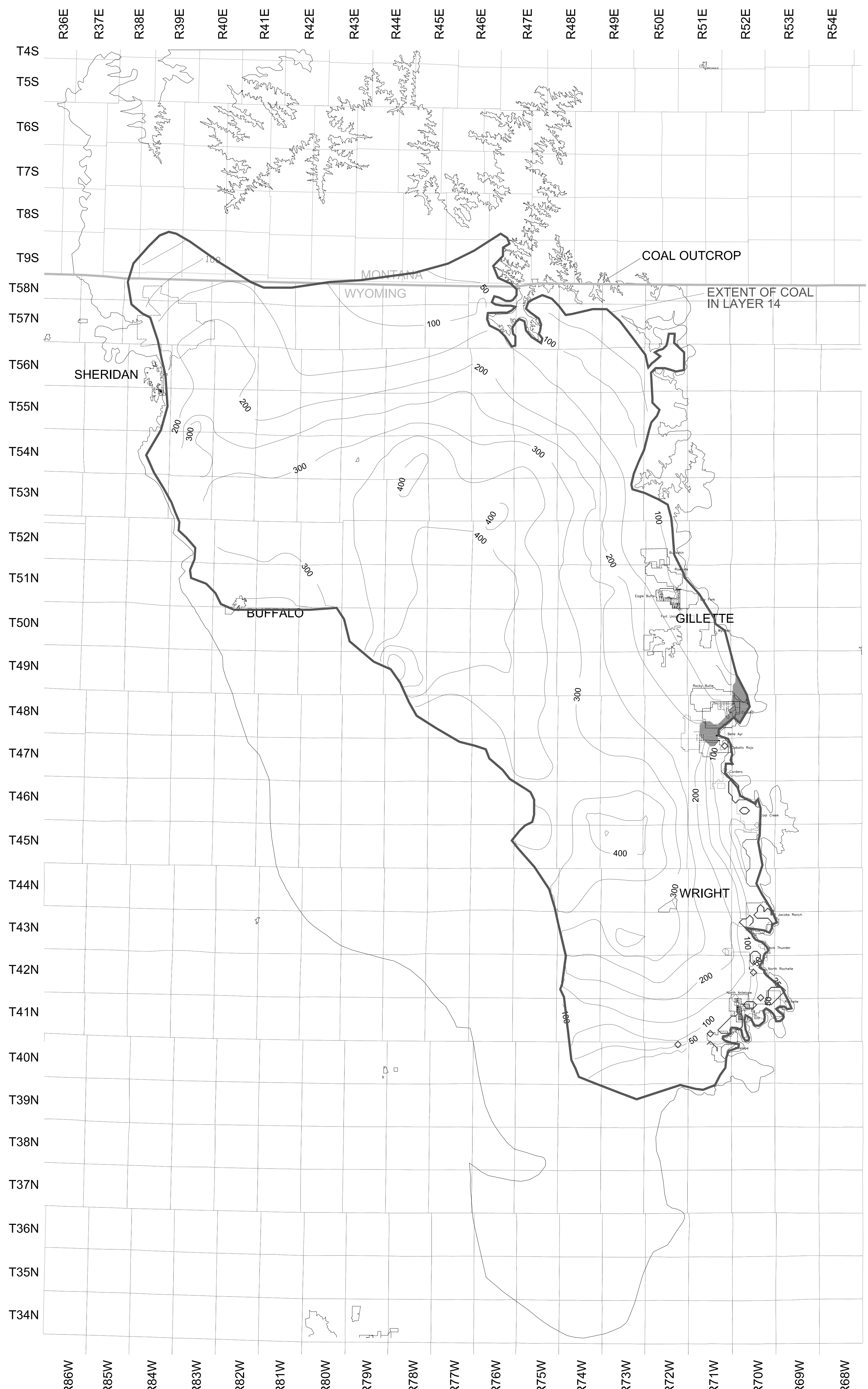
Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-4C MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2012	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-4 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-4C continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 14
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

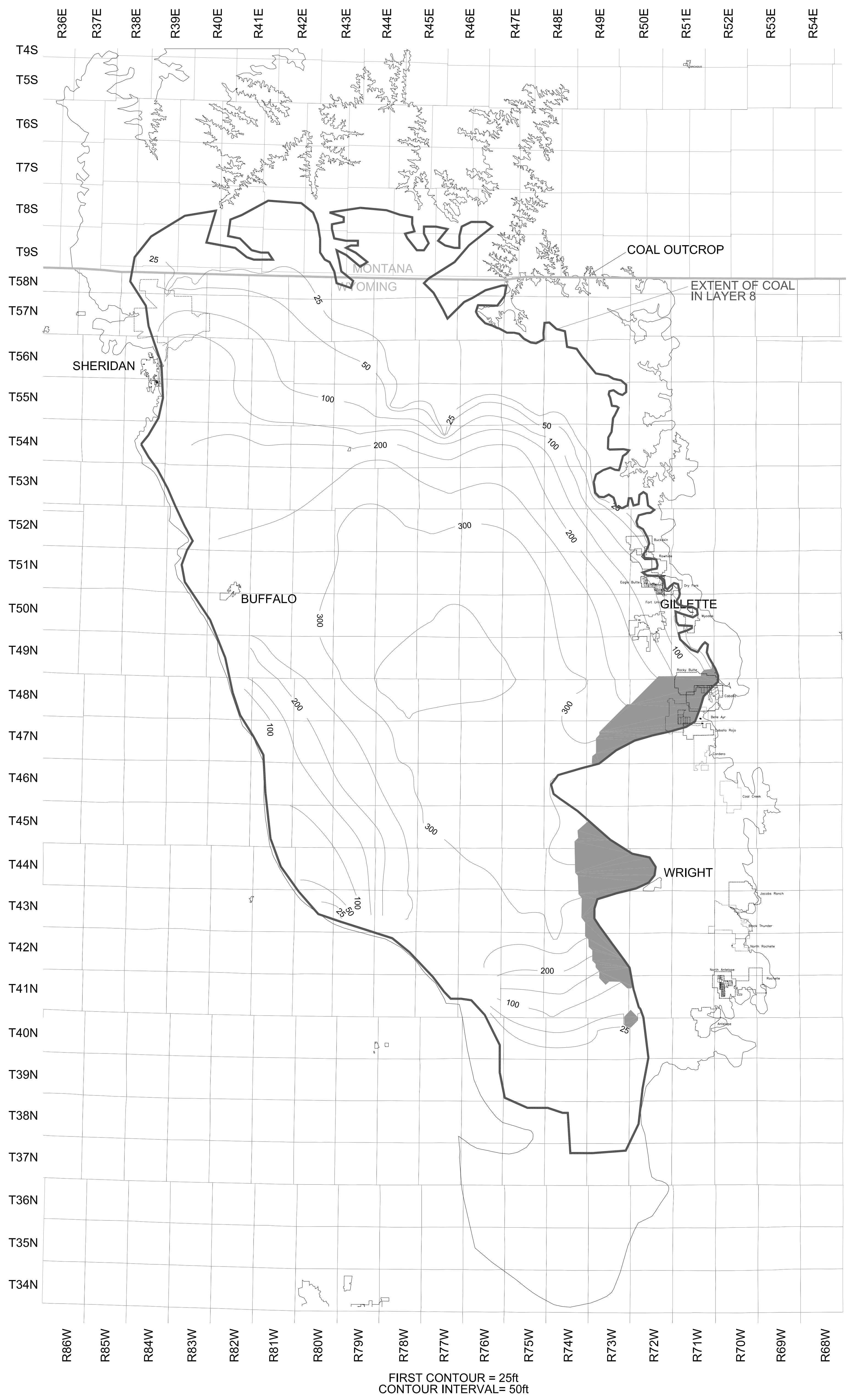
TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-4D
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 14 YEAR 2012

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-4 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-4D continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 8
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

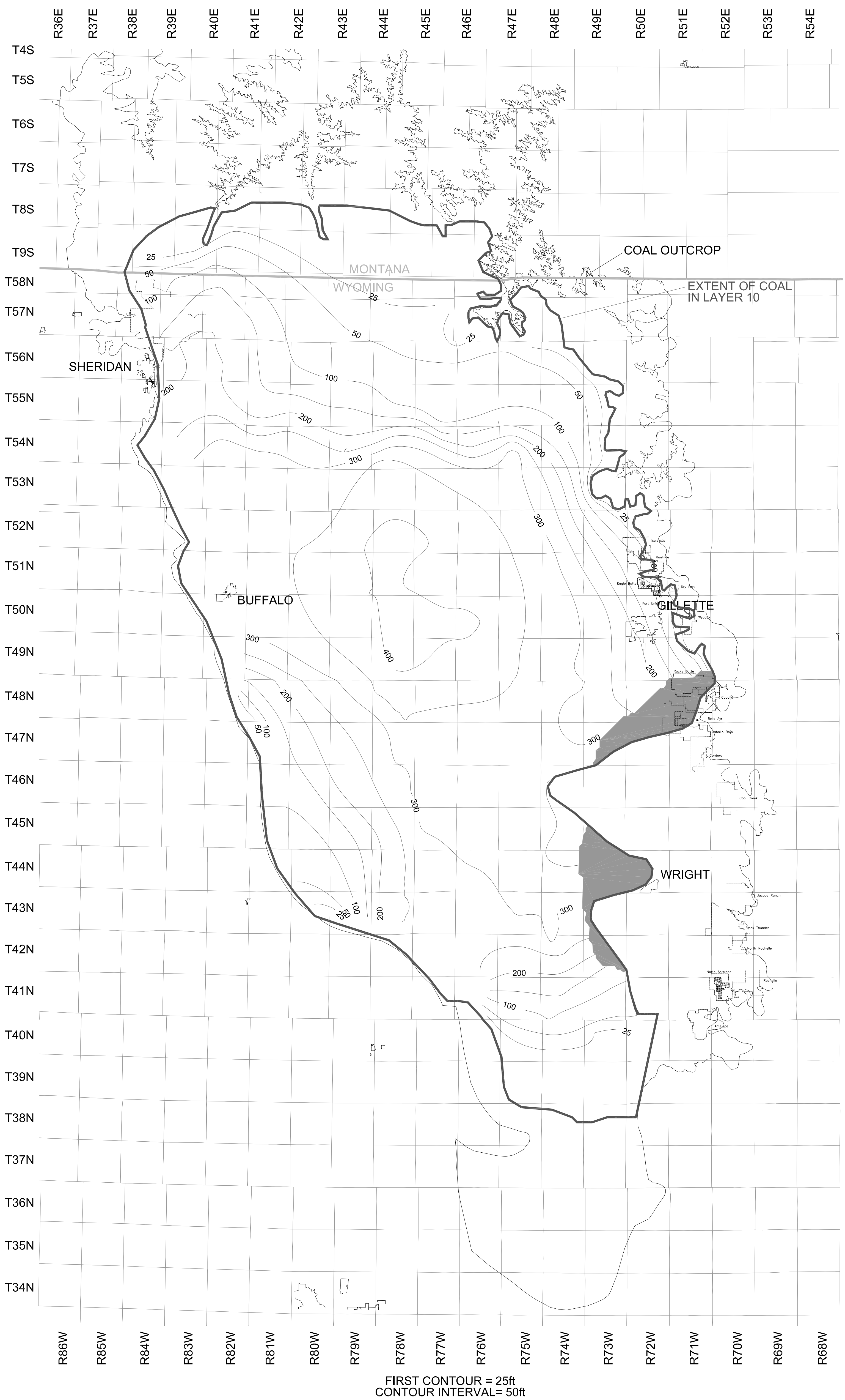
TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-5A
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 8 YEAR 2015

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-5 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-5A continued (11x17)



LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 10
- Dry Cell
- Towns
- Mine Boundary

N

0 7.5 15 30 Miles

Note: Contours are not closed due to insufficient data.

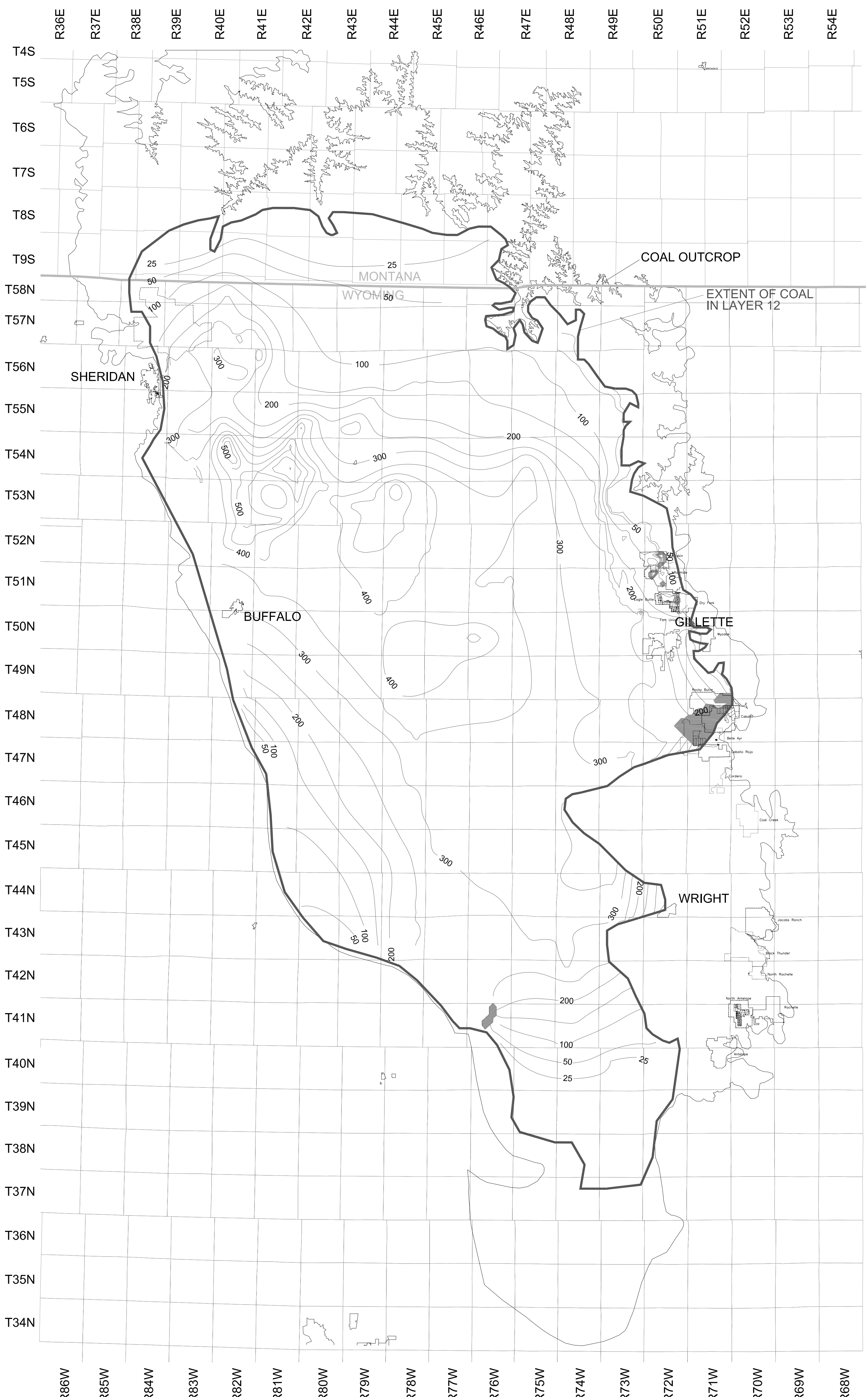
POWDER RIVER BASIN OIL & GAS PROJECT FEIS

TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-5B
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2015

MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-5 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-5B continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 12
- Dry Cell
- Towns
- Mine Boundary

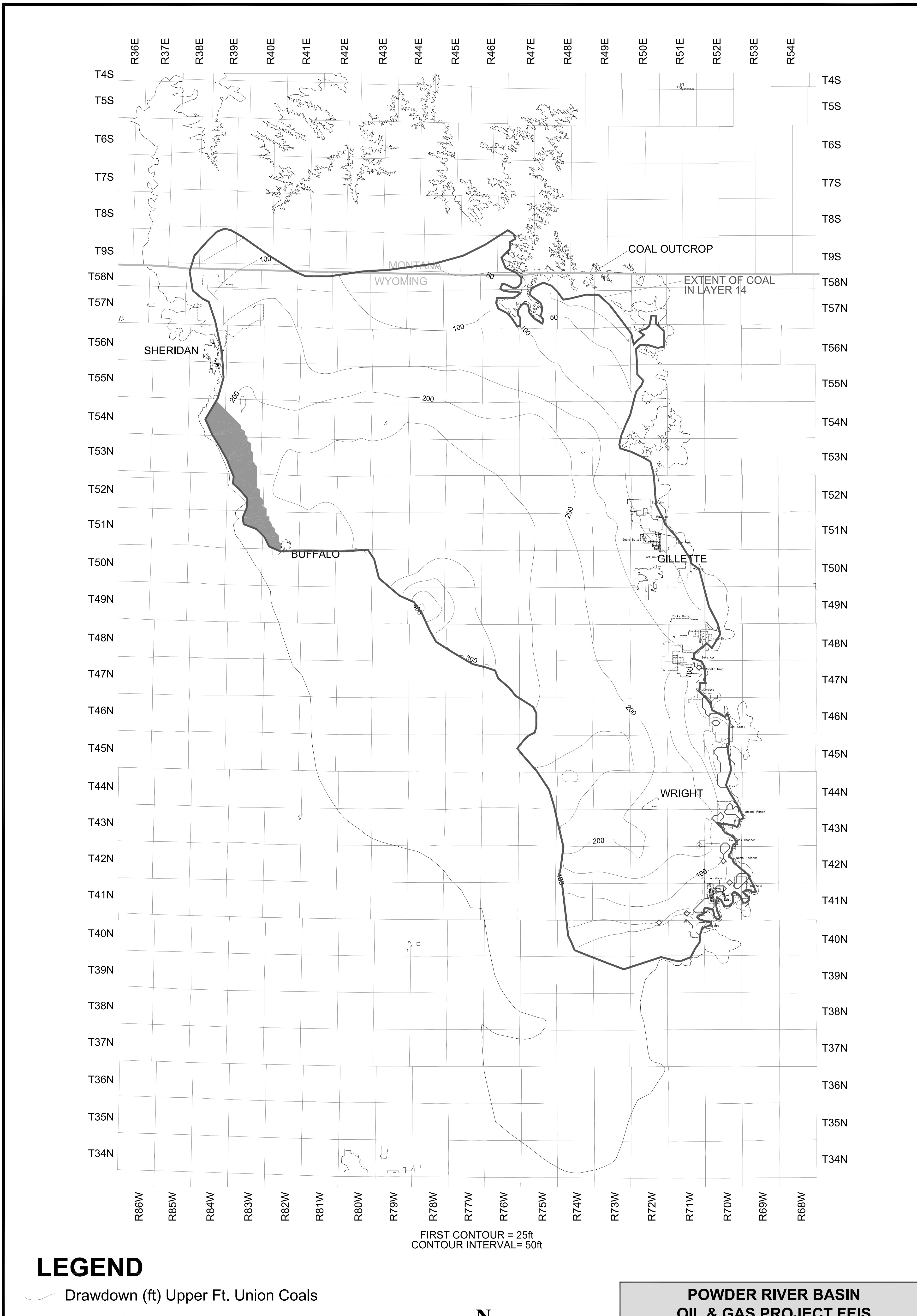
Note: Contours are not closed due to insufficient data.

0 7.5 15 30 Miles

N

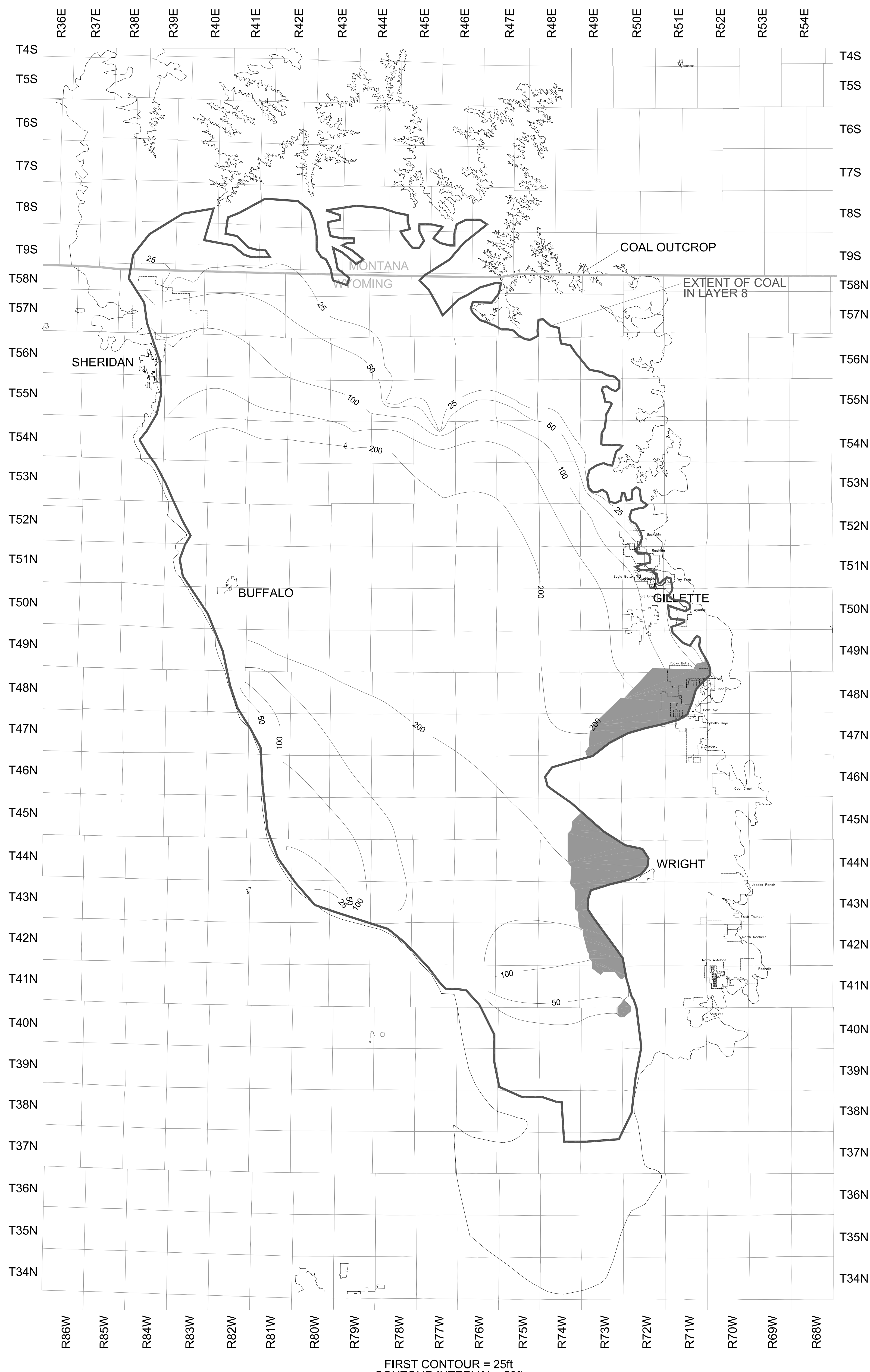
POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-5C MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2015	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-5 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-5C continued (11x17)



POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-5D MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 14 YEAR 2015	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-5 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-5D continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 8
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

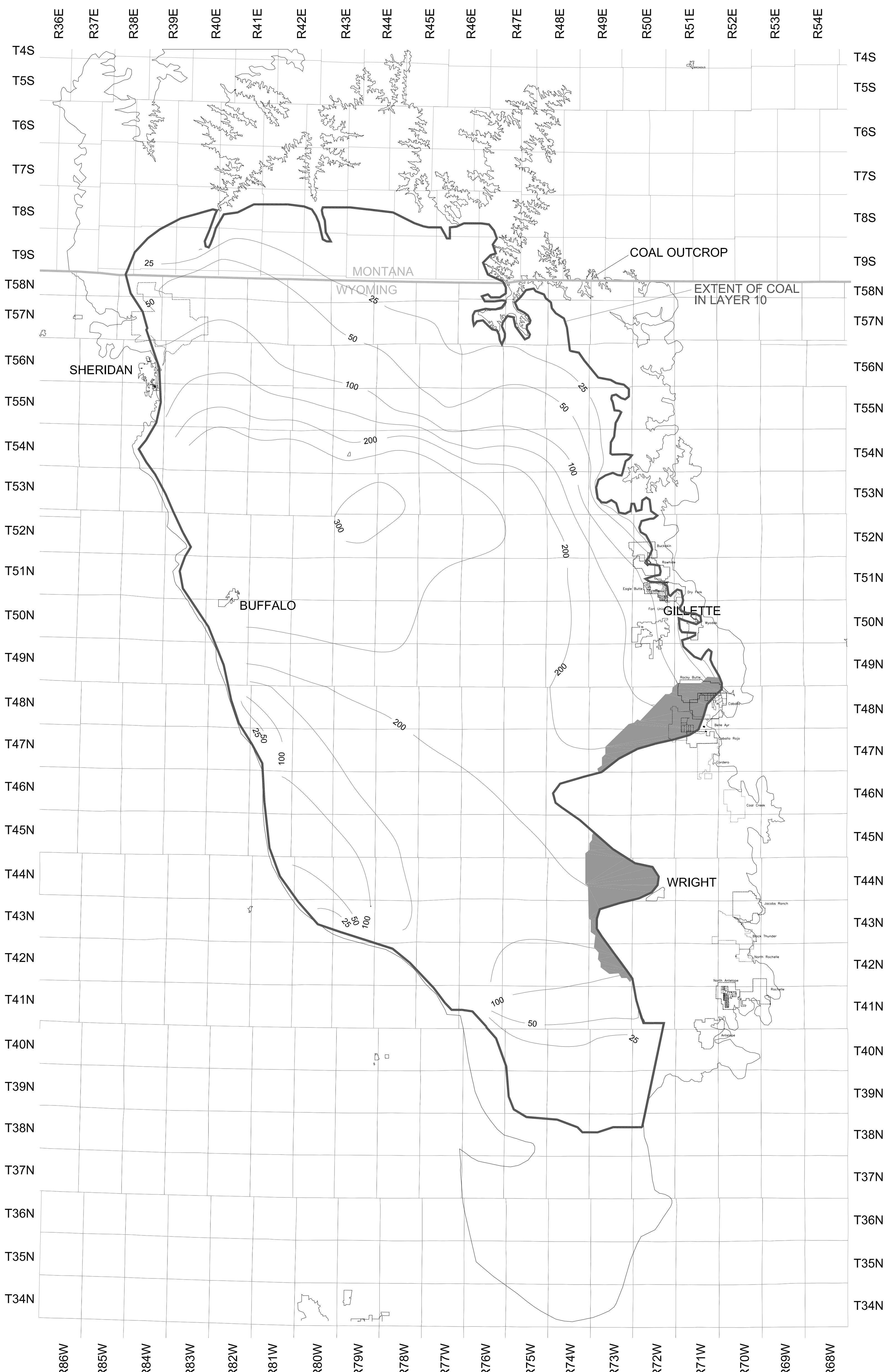
TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-6A
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 8 YEAR 2018

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-6 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-6A continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 10
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN
OIL & GAS PROJECT FEIS

TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-6B
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2018

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-6 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-6B continued (11x17)

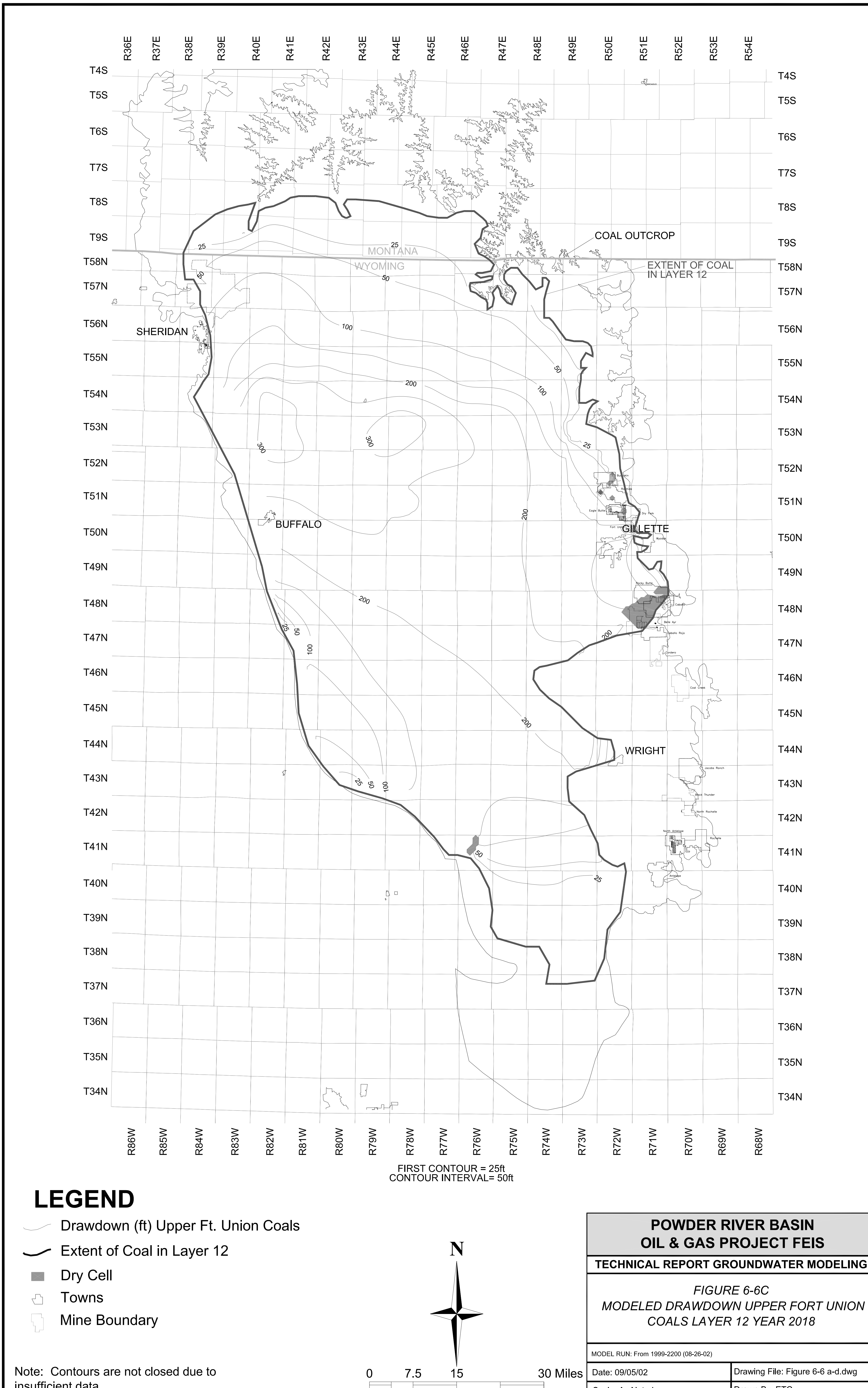
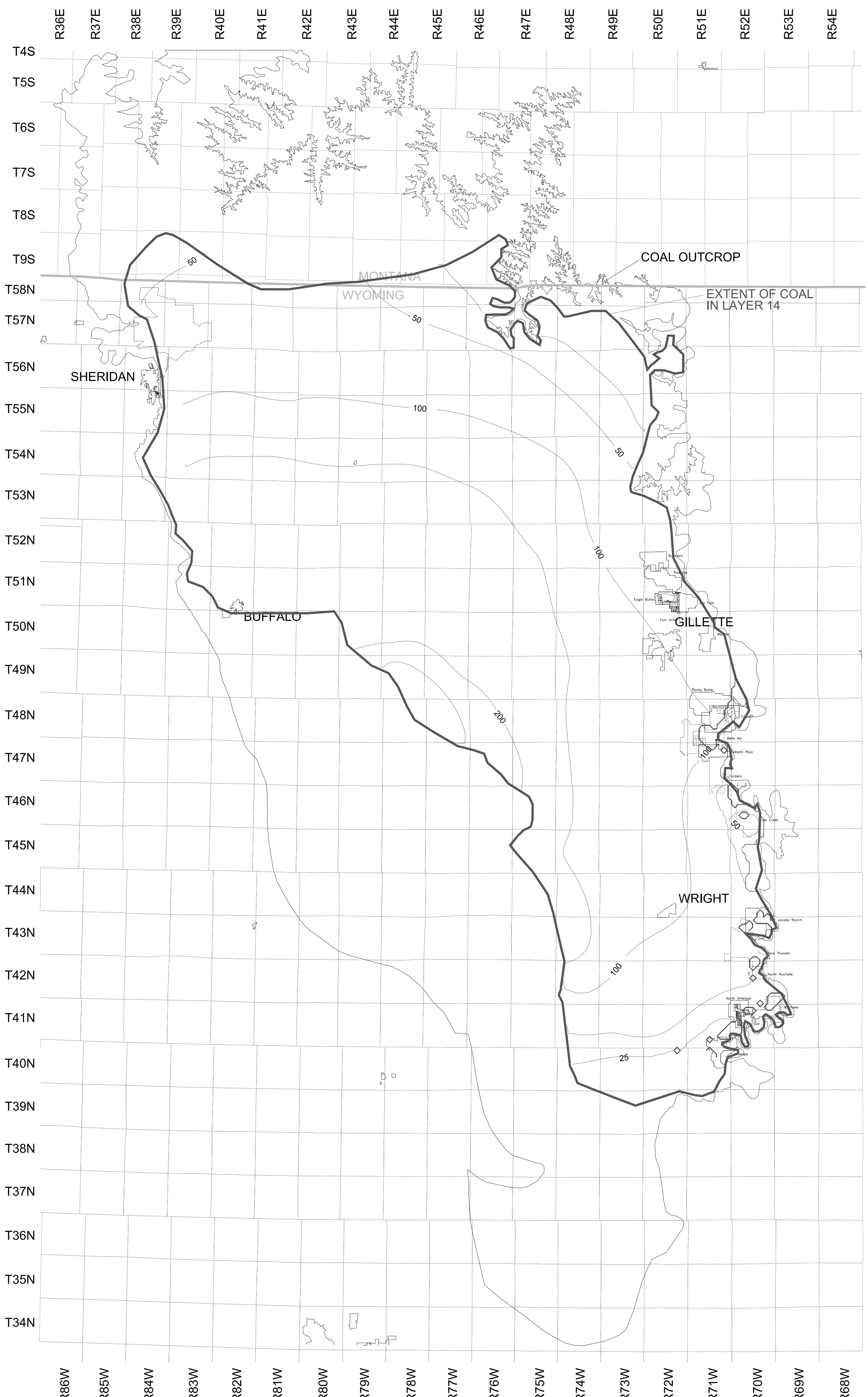

R36E R37E R38E R39E R40E R41E R42E R43E R44E R45E R46E R47E R48E R49E R50E R51E R52E R53E R54E
T4S T5S T6S T7S T8S T9S
T58N T57N T56N T55N T54N T53N T52N T51N T50N T49N T48N T47N T46N T45N T44N T43N T42N T41N T40N T39N T38N T37N T36N T35N T34N
R86W R85W R84W R83W R82W R81W R80W R79W R78W R77W R76W R75W R74W R73W R72W R71W R70W R69W R68W
MONTANA
WYOMING
COAL OUTCROP
EXTENT OF COAL IN LAYER 12
SHERIDAN
BUFFALO
GILLETTE
WRIGHT
FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft
LEGEND
Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 12
Dry Cell
Towns
Mine Boundary
N
0 7.5 15 30 Miles
Note: Contours are not closed due to insufficient data.
POWDER RIVER BASIN OIL & GAS PROJECT FEIS
TECHNICAL REPORT GROUNDWATER MODELING
FIGURE 6-6C
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2018
MODEL RUN: From 1999-2200 (08-26-02)
Date: 09/05/02
Drawing File: Figure 6-6 a-d.dwg
Scale: As Noted
Drawn By: ETC

Figure 6-6C continued (11x17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 14
- Dry Cell
- Towns
- Mine Boundary

N

0 7.5 15 30 Miles

Note: Contours are not closed due to insufficient data.

POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-6D MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 14 YEAR 2018	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-6 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-6D continued (11x17)

The projected rate of drawdown in the coal aquifer is presented by graphs of modeled drawdown versus time at selected locations in the model (Figure 6-7). The locations of the monitoring points are shown on Figure 5-1. The graphs show that water level changes in the coal aquifer that would be induced by CBM development tend to be rapid.

Initial hydraulic head in the coal, as measured by the water level in a well completed in the coal, may be several hundred feet above the top of the coal, particularly in the deep portions of the PRB, where the depth to the coal may exceed 1,300 feet. Removal of water from the coal in these areas during CBM development could result in drawdown of the hydraulic head to the top of the coal at the location of the pumping wells. For reference, an initial hydraulic head of 800 feet would exist where the depth to the coal is 1,200 feet and the depth to water in a well tapping the coal is 400 feet. Even though the thickness of the coal itself may only be 100 feet, maximum drawdown in this example could be as much as 800 feet.

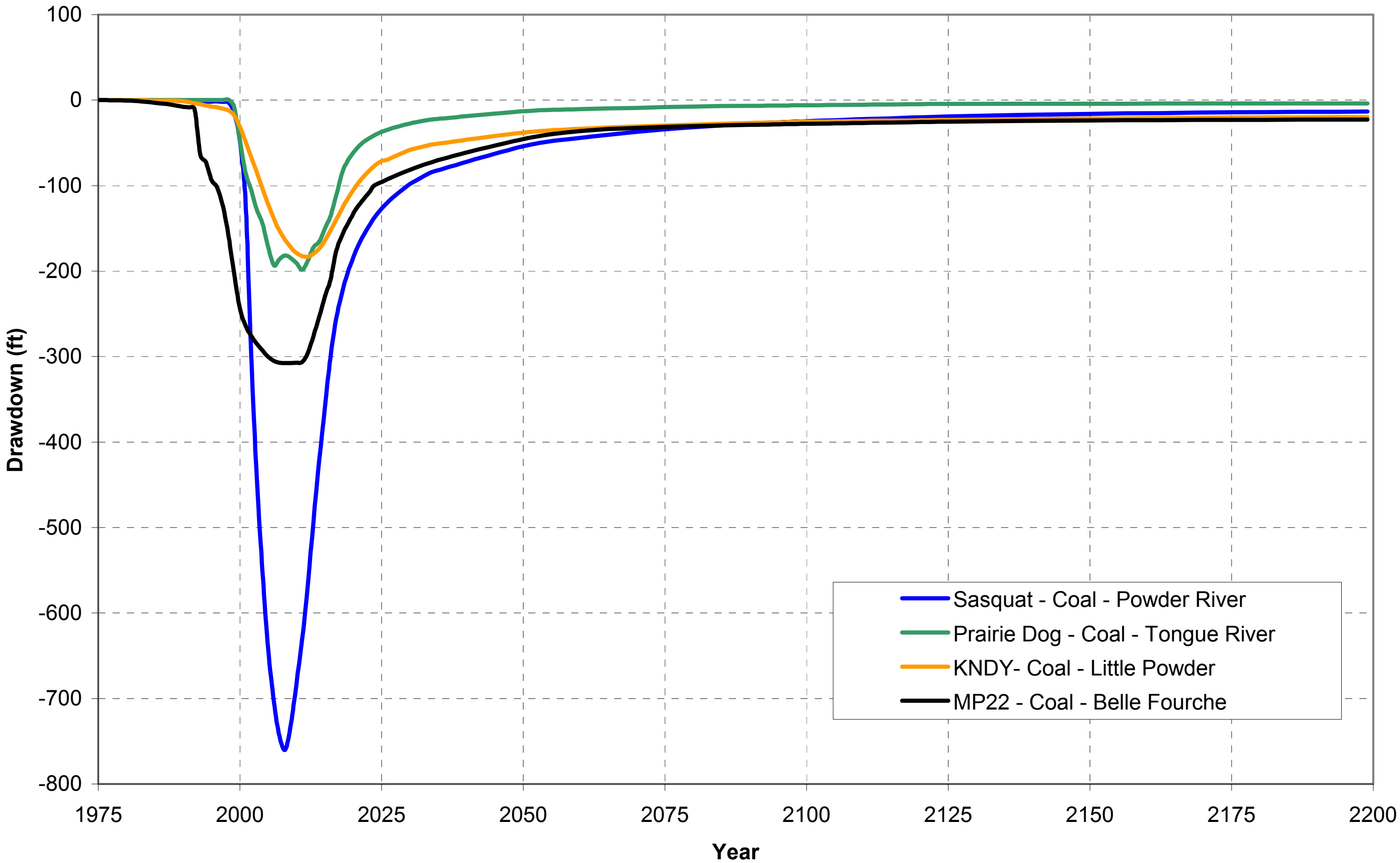
6.2.2 Recovery

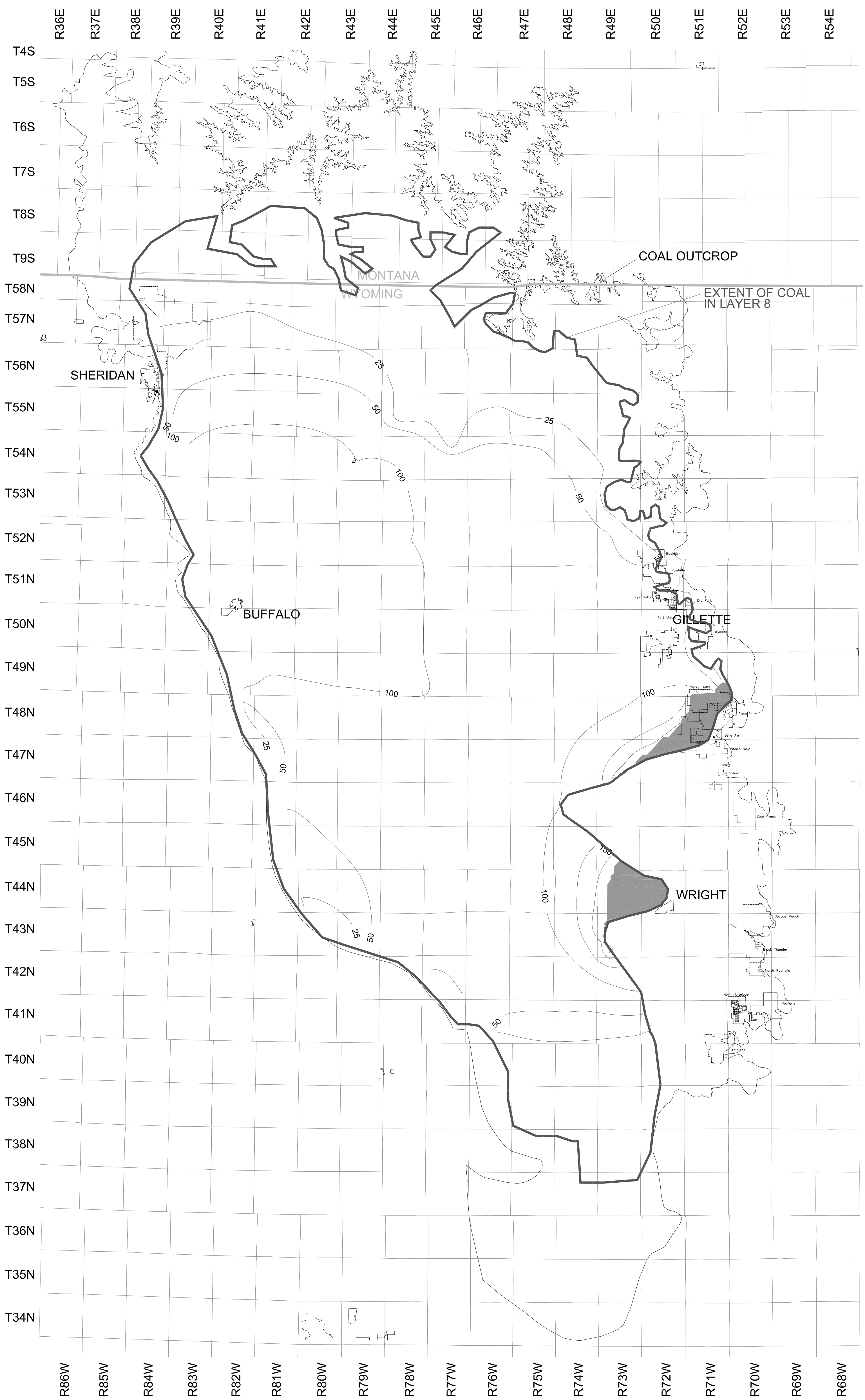
Recovery of water levels in the coal would become apparent after water production began to decline. As modeled, water production is expected to begin to decline about 2008 and end about 2018. Initial recovery would be primarily caused by redistribution of groundwater stored in the surrounding coal. When the stresses of pumping are removed, the groundwater in storage outside the CBM development areas would resaturate and repressurize the areas that were partially depressurized during operations. Longer-term recovery would occur through continued slow leakage from overlying sand aquifers in the Wasatch Formation and sand aquifers in the underlying Fort Union Formation. The amount of groundwater storage within the coal and within the sand units above and below the coal is enormous (Section 2.3.3 and Table 2-4). Almost 750 million acre-feet of recoverable groundwater are stored within the Wasatch-Tongue River sands and coals (Table 2-4). Redistribution would be projected to result in a rapid initial recovery of water levels in the coal. By 2030, 100 feet of drawdown would still exist in most of the coal seams in the basin. Drawdowns of 50 to 200 feet would be typical within portions of the Project Area that have undergone CBM development (Figure 6-8A, B, C, and D).

Complete recovery of the water level would be a long-term process because recharge to the coal aquifer would need to replace groundwater removed from storage during CBM operations. Most of this recharge would come from leakage from overlying and underlying sand and undeveloped coal units. These units would, in turn, be recharged from surface infiltration. Recharge rates would increase temporarily as a result of infiltration of CBM produced water discharged to impoundments and streams. However, based on modeling and information from nested wells, tens of years would be required before these surface recharge influences would appear in the coal. Recharge to the coal in the central part of the PRB through surface infiltration at the outcrop areas would take even longer. The drawdowns projected by the model in 2060 for each of the coal layers are shown in Figures 6-9A, B, C, and D. The drawdowns projected in the model from initial conditions are recovered to less than 50 feet except for localized areas of the basin.

Coal mining along the eastern and northwestern subcrop would result in minimal recharge to the coal from the outcrop areas while the mines are active as a result of the groundwater sink caused by pit dewatering. As mines are reclaimed and eventually shut down, the backfilled areas would become long-term recharge zones for the coal aquifer. Infiltration through backfill areas may be significant because the permeability of the backfill materials tends to be much higher than in the original, unmined materials. In addition, most of the creeks would be diverted over these backfilled areas, providing an important source of recharge water.

Figure 6-7 Modeled Drawdown vs. Time for Selected Upper Fort Union Monitoring Locations





FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 8
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN
OIL & GAS PROJECT FEIS

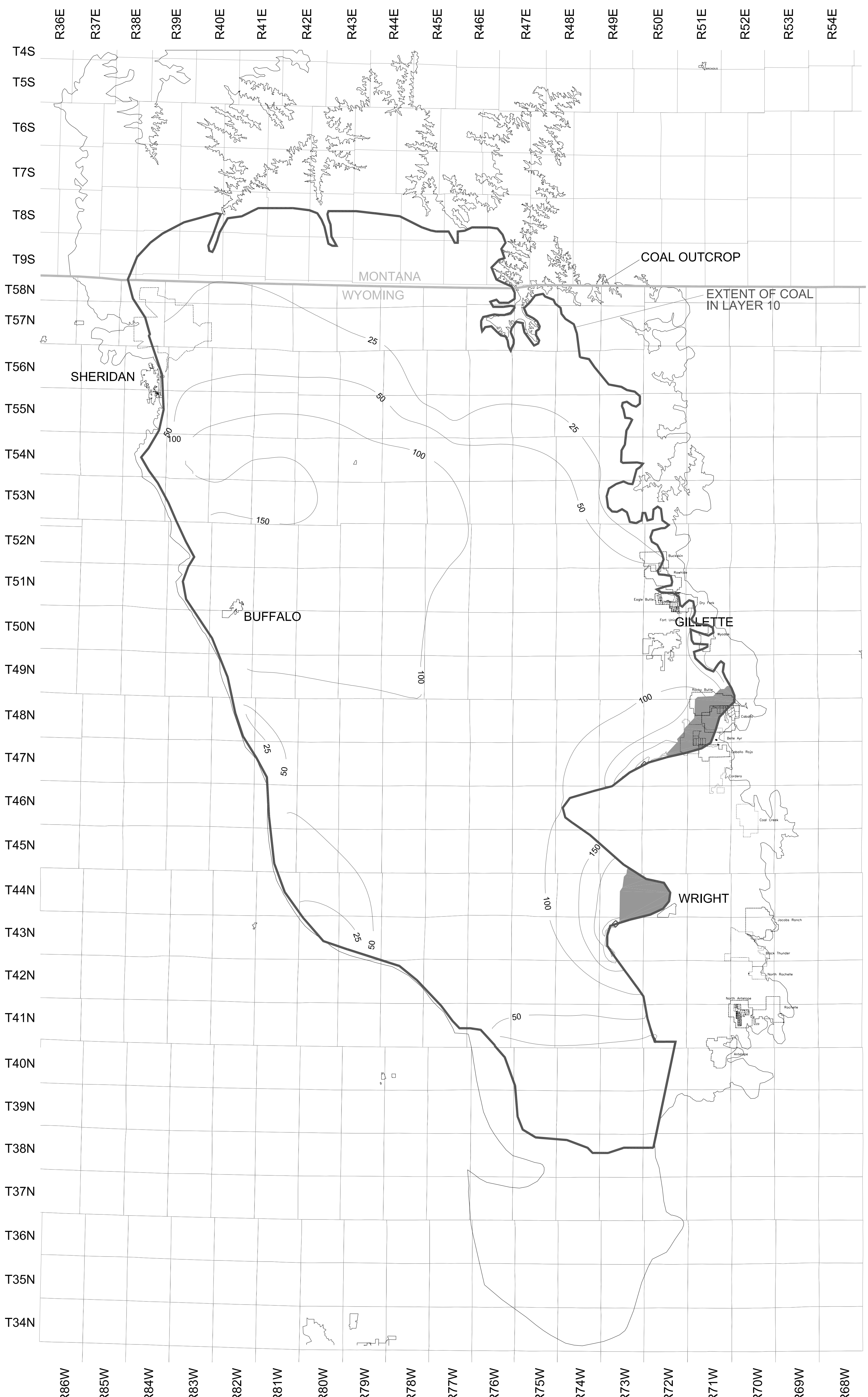
TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-8A
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 8 YEAR 2030

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-8 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-8A continued (11 x 17)



FIRST CONTOUR = 25ft
CONTOUR INTERVAL= 50ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 10
- Dry Cell
- Towns
- Mine Boundary

N

Note: Contours are not closed due to insufficient data.

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

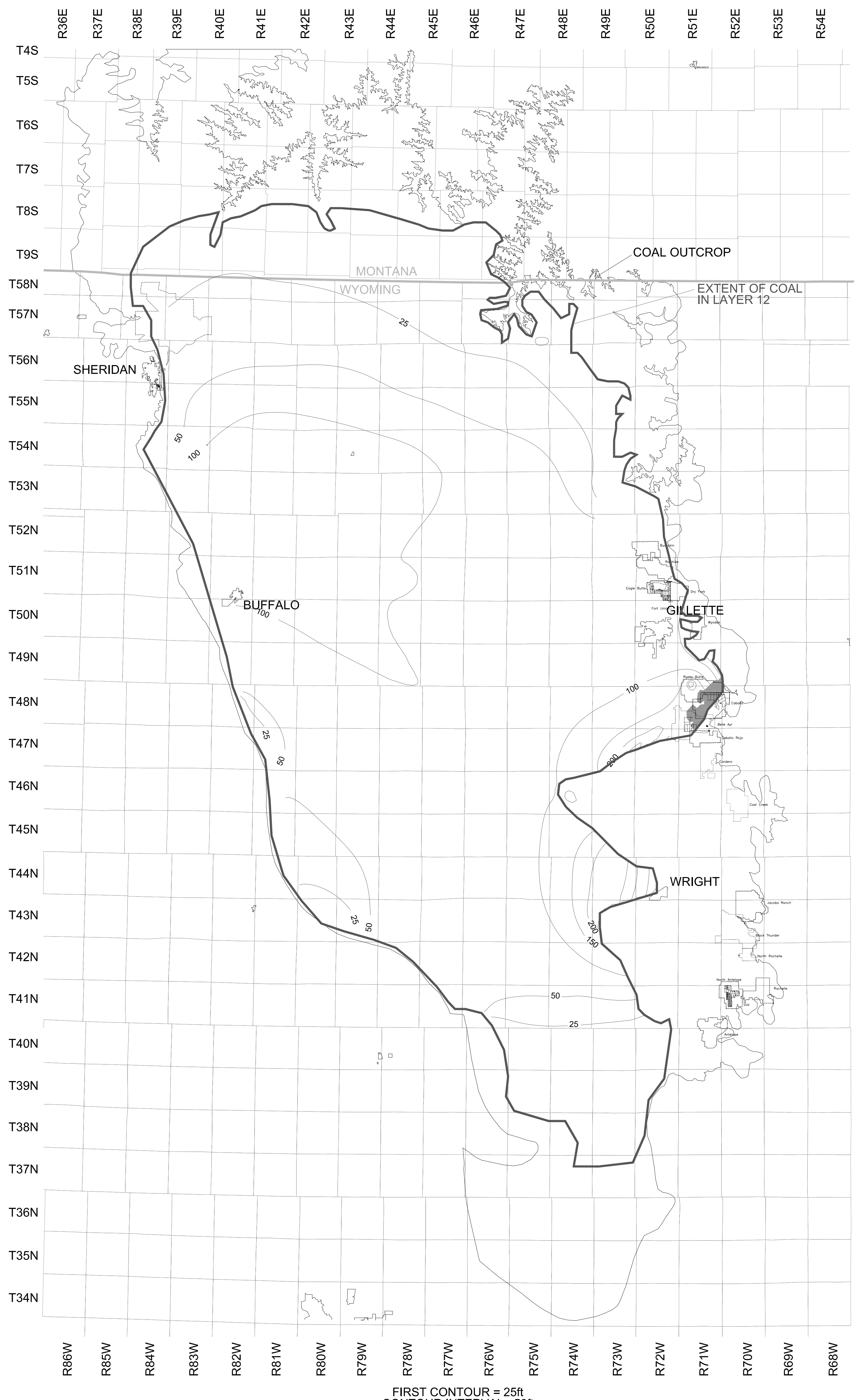
TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-8B
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2030

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-8 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-8B continued (11 x 17)



LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 12
- Dry Cell
- Towns
- Mine Boundary

Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

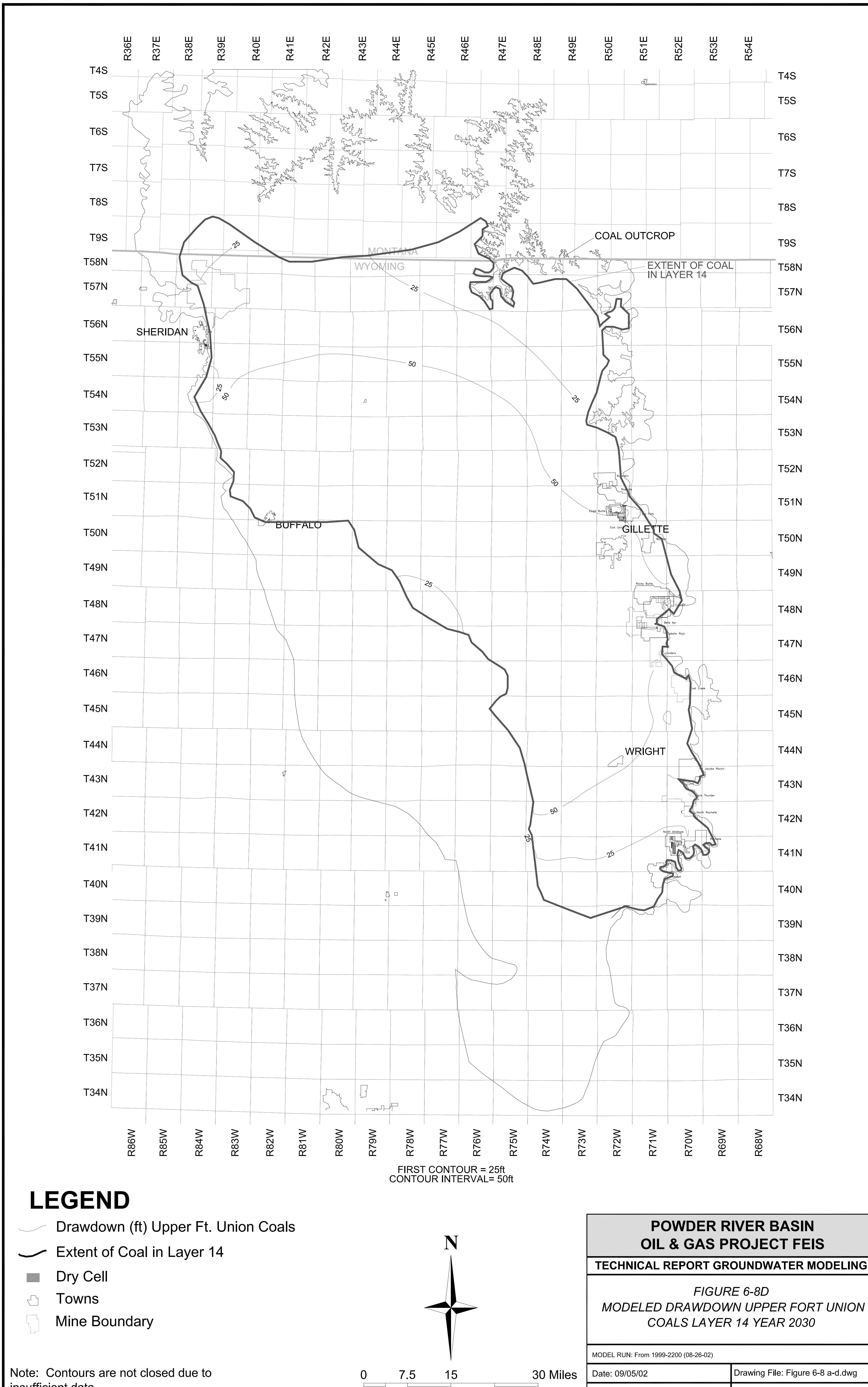
POWDER RIVER BASIN OIL & GAS PROJECT FEIS

TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-8C
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2030

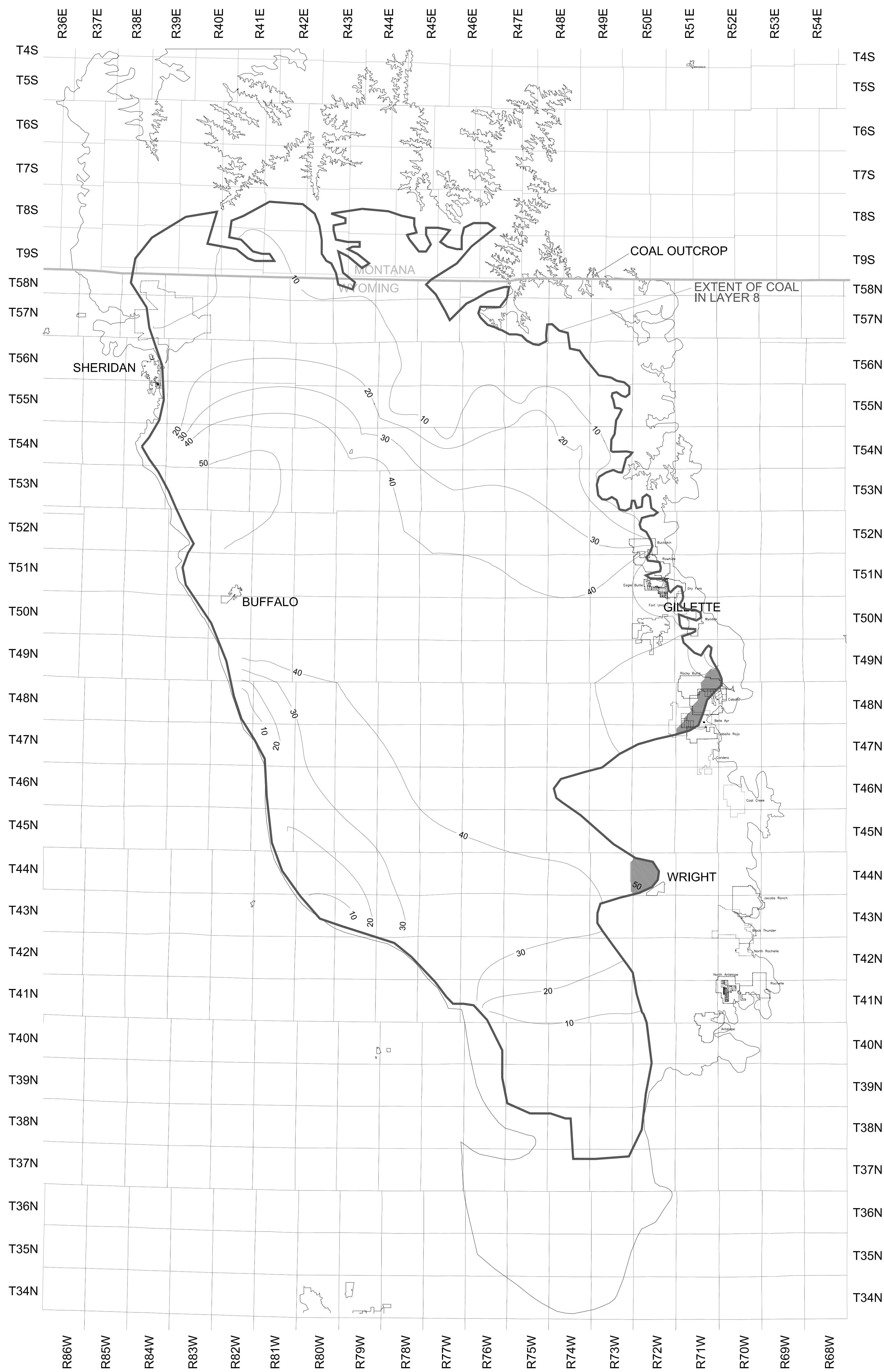
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-8 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-8C continued (11 x 17)



POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-8D MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 14 YEAR 2030	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-8 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-8D continued (11 x 17)



CONTOUR INTERVAL= 10ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 8
- Dry Cell
- Towns
- Mine Boundary

N

0 7.5 15 30 Miles

Note: Contours are not closed due to insufficient data.

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

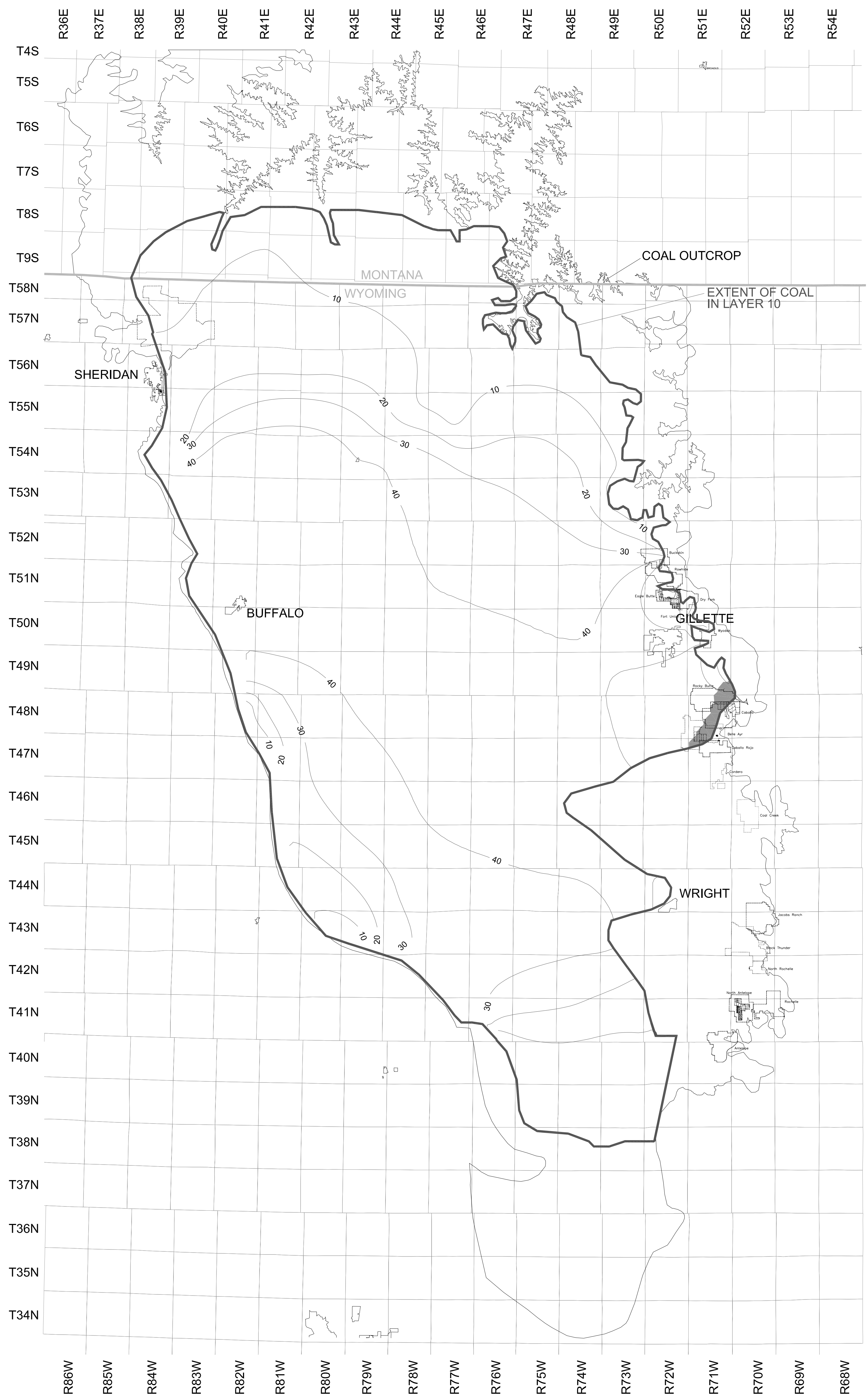
TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-9A
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 8 YEAR 2060

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-9 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-9A continued (11 x 17)



CONTOUR INTERVAL= 10ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 10
- Dry Cell
- Towns
- Mine Boundary

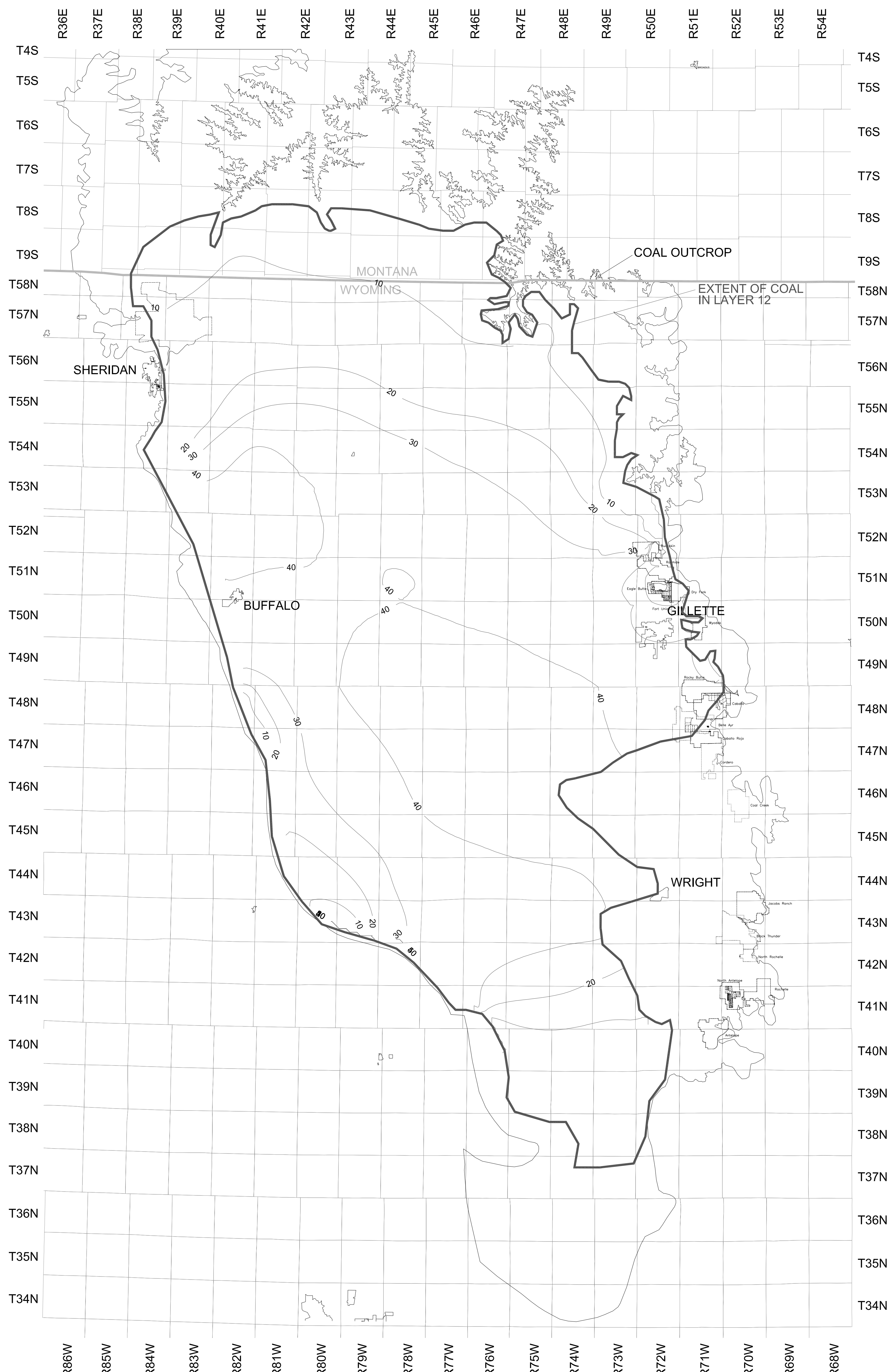
Note: Contours are not closed due to insufficient data.

N

0 7.5 15 30 Miles

POWDER RIVER BASIN OIL & GAS PROJECT FEIS	
TECHNICAL REPORT GROUNDWATER MODELING	
FIGURE 6-9B MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 10 YEAR 2060	
MODEL RUN: From 1999-2200 (08-26-02)	
Date: 09/05/02	Drawing File: Figure 6-9 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-9B continued (11 x 17)



CONTOUR INTERVAL= 10ft

LEGEND

- Drawdown (ft) Upper Ft. Union Coals
- Extent of Coal in Layer 12
- Dry Cell
- Towns
- Mine Boundary

N

0 7.5 15 30 Miles

Note: Contours are not closed due to insufficient data.

POWDER RIVER BASIN OIL & GAS PROJECT FEIS

TECHNICAL REPORT GROUNDWATER MODELING

FIGURE 6-9C
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 12 YEAR 2060

MODEL RUN: From 1999-2200 (08-26-02)

Date: 09/05/02	Drawing File: Figure 6-9 a-d.dwg
Scale: As Noted	Drawn By: ETC

Figure 6-9C continued (11 x 17)

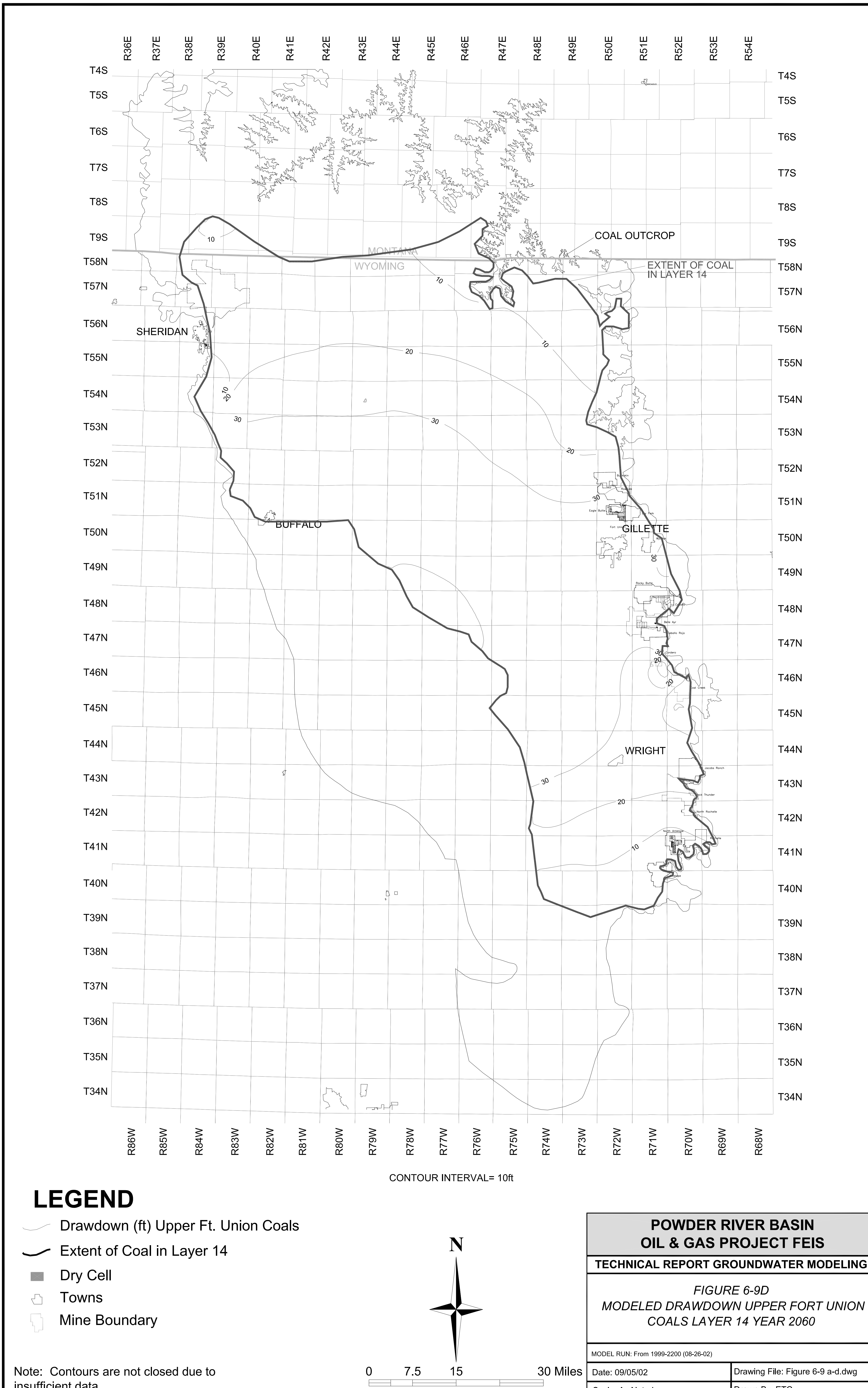

R36E R37E R38E R39E R40E R41E R42E R43E R44E R45E R46E R47E R48E R49E R50E R51E R52E R53E R54E
T4S T5S T6S T7S T8S T9S
T58N T57N T56N T55N T54N T53N T52N T51N T50N T49N T48N T47N T46N T45N T44N T43N T42N T41N T40N T39N T38N T37N T36N T35N T34N
R86W R85W R84W R83W R82W R81W R80W R79W R78W R77W R76W R75W R74W R73W R72W R71W R70W R69W R68W
MONTANA
WYOMING
COAL OUTCROP
EXTENT OF COAL IN LAYER 14
SHERIDAN
BUFFALO
GILLETTE
WRIGHT
10
20
30
CONTOUR INTERVAL= 10ft
LEGEND
Drawdown (ft) Upper Ft. Union Coals
Extent of Coal in Layer 14
Dry Cell
Towns
Mine Boundary
Note: Contours are not closed due to insufficient data.
N
0 7.5 15 30 Miles
POWDER RIVER BASIN
OIL & GAS PROJECT FEIS
TECHNICAL REPORT GROUNDWATER MODELING
FIGURE 6-9D
MODELED DRAWDOWN UPPER FORT UNION COALS LAYER 14 YEAR 2060
MODEL RUN: From 1999-2200 (08-26-02)
Date: 09/05/02
Drawing File: Figure 6-9 a-d.dwg
Scale: As Noted
Drawn By: ETC

Figure 6-9D continued (11 x 17)

The projected recovery of water levels after CBM development and coal mining operations end is illustrated in the hydrographs for selected locations in the model (Figure 6-7). The graphs show water levels recovering to within 55 to 65 feet (75 to 80 percent) of pre-operational conditions approximately 25 years after CBM operations end. However, the rate of recovery would slow dramatically after this initial period, eventually recovering to within less than 20 feet (95 percent) of pre-operational conditions over the next 100 years or so.

Drawdown and recovery within the shallow and deep sands of the Wasatch Formation cannot be accurately projected by the regional model because of the variability of the sand units and the general lack of data available to calibrate the model layers that represent the Wasatch Formation.

6.3.2 Recharge

Some of the extracted groundwater released to surface drainages and impoundments would recharge shallow bedrock (the Wasatch Formation). A portion of the released water would recharge the alluvium. In turn, the alluvium along many of the creek valleys would recharge the underlying Wasatch sands. Several studies of losses in water flow along creeks during dry weather have shown that a considerable portion of the discharged water infiltrates the alluvium within a few miles of the surface discharge outfall. Shallow bedrock monitoring wells located close to areas where CBM produced water is discharging into creeks or impoundments have shown increases in water level, indicating that recharge is occurring. The nature of recharge in any area is directly related to the permeability of the surface exposures of the Wasatch Formation under creeks and ponds.

The recharge effect was evaluated in this analysis by examining the area of affected surface drainages and the probable range of vertical infiltration rates into the Wasatch Formation below the creeks and ponds. The total discharge from CBM operations was obtained from the model output for each of the affected sub-watersheds(Table 6-1). This projected water production would be managed according to the water handling options identified for each sub-watershed under Alternative 1 (Table 2-9 of the FEIS). The projected net recharge is calculated based on the percentage of the produced water handled by each method and the projected loss through infiltration (Tables 3-1 and 4-3). This infiltration has been characterized as an area recharge, considering the scale and limited detail in the regional model.

The calculated net recharge volume, on a year-by-year basis, was divided by the projected area of CBM development within each sub-watershed to obtain an equivalent recharge rate for the area, in inches per year (Table 6-2). This additional recharge was then input into the model for the area of CBM development within each sub-watershed during the period when CBM operations are expected to be active.

Table 6-2
Annual Recharge Rate Projected in the Model by Sub-Watershed (2002 to 2017) Under Alternative 1
(Recharge rate applied to developed CBM areas [inches per year])

Sub-watershed	Developed Area (acres)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Upper Tongue River	10,246,277	0.192	0.260	0.340	0.388	0.414	0.440	0.450	0.486	0.484	0.468	0.419	0.379	0.303	0.243	0.175	0.107
Upper Powder River	78,184,723	0.191	0.247	0.289	0.317	0.338	0.350	0.348	0.315	0.282	0.248	0.210	0.168	0.117	0.069	0.051	0.038
Salt Creek	298,848	0.033	0.033	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Crazy Woman Creek	11,776,274	0.091	0.137	0.173	0.200	0.219	0.237	0.246	0.223	0.198	0.180	0.152	0.128	0.102	0.076	0.060	0.046
Clear Creek	17,828,989	0.108	0.154	0.198	0.243	0.283	0.316	0.328	0.332	0.329	0.326	0.283	0.242	0.197	0.159	0.119	0.077
Middle Powder River	6,818,630	0.165	0.174	0.182	0.188	0.184	0.161	0.133	0.144	0.147	0.149	0.138	0.125	0.110	0.094	0.076	0.053
Little Powder River	13,350,050	0.192	0.190	0.186	0.189	0.174	0.161	0.130	0.132	0.135	0.135	0.122	0.111	0.095	0.080	0.064	0.050
Antelope Creek	11,399,624	0.176	0.193	0.218	0.233	0.249	0.253	0.250	0.238	0.229	0.214	0.193	0.169	0.135	0.098	0.080	0.060
Upper Cheyenne River	5,660,490	0.241	0.226	0.214	0.196	0.185	0.161	0.159	0.149	0.135	0.118	0.113	0.077	0.060	0.030	0.030	0.030
Upper Belle Fourche River	35,874,382	0.340	0.329	0.318	0.312	0.307	0.286	0.245	0.235	0.224	0.215	0.197	0.175	0.146	0.093	0.078	0.063

Note: Recharge rates shown include average recharge of 0.03 inches per year from precipitation and projected recharge resulting from water handling methods.

6.4 Potential Impacts to Groundwater Use

6.4.1 Water Wells

Impacts to individual water wells completed within the coal and in sands above the coal would depend on proximity to CBM production wells, depth, completion interval, and the yield required to maintain it as a usable source. Drawdown of water levels in coal aquifers caused by CBM development may affect individual well users by reducing well yield and inducing methane emissions.

Under Alternative 1, the model projects more than 800 feet of coal aquifer drawdown near the centers of active CBM development. (Figures 6-1A, B, C, and D through 6-6A, B, C, and D). The maximum available drawdown (the hydraulic pressure head) in the coal aquifer in the affected areas ranges from 300 to 1,400 feet. Most individual water supply wells in the coal seam do not exceed 600 feet in depth and have up to 300 feet of available drawdown. Pumps typically are set between 50 and 200 feet below the static water level in the well.

Impacts, in terms of well yield or availability, are likely to be an issue only if the drawdown exceeds about 20 to 30 percent of the amount available at any location. This area would tend to coincide with the area of drawdown in excess of approximately 100 feet. The decreased head may cause the pump discharge to decrease. However, yield may be restored by installing a larger pump if sufficient available drawdown remains in the well. In cases where the drawdown causes the water level in a well to drop below the intake of the pump, the pump may be lowered in the well.

Changes in water level in wells are not expected to be as significant in the aquifers above or below the coal because the coal is confined both above and below by low-permeability claystone layers over most of the PRB. This claystone unit restricts hydraulic communication between the coal and the overlying Wasatch sands. The response of existing monitoring wells located in sands above developed coals indicates that a significant period of time (typically several years) likely would pass before drawdown effects caused by pumping groundwater from the coal are apparent in the overlying Wasatch sands. The integrity of the confining layer may be compromised locally by water supply wells screened through both the coal and the overlying sands, deteriorating well casings, or poorly plugged oil and gas wells or exploratory drill holes. However, these isolated local influences would not affect regional results.

Artesian flow has been reported in wells located near the Powder River, where the hydraulic head from the deep coal aquifer extends to the surface. Groundwater has been discharging in this area, in part to artesian wells. Reductions in hydraulic head projected by the model within the coal aquifer likely would reduce or eliminate artesian flow in water wells. Artesian flow in wells likely would not recover until hydraulic head in the coal aquifer recovers sufficiently after CBM development ends.

6.4.2 Methane Emissions

Withdrawal of water from the coal aquifer during CBM development can depressurize the coal aquifer and induce the release of methane into nearby water wells completed in the coal aquifer. Individual users of wells completed in the coal aquifer may experience increased methane emissions if the wells fall within an area that experiences noticeable depressurization in the aquifer.

Records of first indications of methane production in monitoring wells that have experienced drops in water level caused by mining indicate that methane emission from the coal can occur with as little as 50 feet of head drop (Belle Ayr Mine groundwater monitoring data). Consequently, coal wells within the predicted 50-foot drawdown area may be susceptible to this impact. Methane emissions by a well pose a potential explosive safety hazard, particularly if gases can build up in an enclosed space. Well houses and basements located within the potential 50-foot drawdown area associated with operational CBM fields should be well ventilated and periodically checked for methane gas.

6.5 Potential Impacts to Groundwater Flow Systems

The groundwater resources of the PRB are vast (Table 2-4), and regional flow within and out of the PRB would not be noticeably affected under Alternative 1. Nearly 1.4 billion acre-feet of recoverable groundwater have been estimated to exist within the Wasatch and Fort Union Formations (FEIS, Table 3-5). The projected CBM water production from 2002 to 2017, about 3 million acre-feet (FEIS, Table 2-8), represents only about 0.2 percent of the recoverable groundwater. The modeled removal of water during coal mining through 2033, about 1 million acre-feet (Table 6-3), represents less than 0.1 percent of the recoverable groundwater. Any noticeable effects on local groundwater flow systems would be expressed as effects on existing springs or groundwater discharge areas.

Table 6-3
Water Removed During Coal Mining

Year	Rates [m^3/day]	MBBL/yr	AC-FT/yr
1975	0	-	
1976	2277.1	5,200	670
1977	48863	112,200	14,461
1978	45614	104,700	13,495
1979	37335	85,700	11,046
1980	14362	33,000	4,253
1981	16846	38,700	4,988
1982	45496	104,400	13,456
1983	45744	105,000	13,533
1984	47764	109,600	14,126
1985	28001	64,300	8,288
1986	45554	104,600	13,482
1987	28993	66,600	8,584
1988	95765	219,800	28,330
1989	78023	179,100	23,084
1990	130840	300,300	38,706
1991	144000	330,500	42,598
1992	175320	402,400	51,865
1993	121210	278,200	35,857
1994	50370	115,600	14,900
1995	92510	212,400	27,376
1996	150080	344,500	44,403
1997	129430	297,100	38,293
1998	70322	161,400	20,803
1999	61942	142,200	18,328
2000	74081	170,100	21,924
2001	149980	344,300	44,377
2002	114840	263,600	33,975
2003	124370	285,500	36,798
2004	80608	185,000	23,845
2005	74875	171,900	22,156
2006	53963	123,900	15,969

Table 6-3
Water Removed During Coal Mining

Year	Rates [m^3/day]	MBBL/yr	AC-FT/yr
2007	100790	231,400	29,825
2008	80434	184,600	23,793
2009	95921	220,200	28,382
2010	46071	105,800	13,637
2011	71810	164,800	21,241
2012	49608	113,900	14,681
2013	43931	100,800	12,992
2014	24576	56,400	7,269
2015	36217	83,100	10,711
2016	27771	63,700	8,210
2017	28954	66,500	8,571
2018	21195	48,700	6,277
2019	34745	79,800	10,285
2020	39740	91,200	11,755
2021	32770	75,200	9,693
2022	16613	38,100	4,911
2023	782.55	1,800	232
2024	36631	84,100	10,840
2025	26448	60,700	7,824
2026	46554	106,900	13,778
2027	30013	68,900	8,881
2028	62759	144,100	18,573
2029	29652	68,100	8,777
2030	27563	63,300	8,159
2031	5419.9	12,400	1,598
2032	4877.4	11,200	1,444
2033	3027.9	7,000	902
2034	0	-	
2050	0	-	
2060	0	-	
2070	0	-	
2080	0	-	
2090	0	-	
2100	0	-	
2125	0	-	
2150	0	-	
2175	0	-	
2199	0	-	
		7,814,500	1,007,211

Source: Regional Model

6.5.1 Existing Springs

The public has expressed concern over the potential effects of CBM development on springs that issue from clinker outcrops, such as the Moyer Springs located north of Gillette in Section 30, T51N R71W. Moyer Springs is located at the base of an exposed clinker deposit in the outcrop area of the Roland-Smith coal seam. The springs recharge through surface infiltration and lateral movement of water from adjacent clinker and alluvium. The springs issue along a low-permeability zone at the contact between the clinker and the coal. Large areas of clinker are exposed northeast and southeast of Moyer Springs

(Williams 1978). This exposure allows a large amount of recharge to the clinker by infiltration of rainfall and snowmelt. Hodson et al. (1973) reported a flow of 200 gallons per minute from Moyer Springs.

No decrease in spring flows would be anticipated under Alternative 1 where the springs result from flow along a near-surface zone of low permeability intercepting the surface. Many springs in the Project Area, including Moyer Springs, represent this type. A contact of low permeability inhibits flow between the clinker and the coal. The presence of a low-permeability zone between the clinker and the coal channels water in the clinker to the spring rather than recharging the coal. A decrease in recharge to the spring (which is not projected to occur under Alternative 1) could reduce flow for this type of spring.

The natural discharge of springs in the Project Area could be affected by a reduction in the hydraulic head in an aquifer unit, if the aquifer that experiences the reduction in hydraulic head were the spring's source aquifer. Spring flow could decrease or stop under these conditions. Spring flow likely would not recover until the hydraulic head in the coal aquifer recovers sufficiently after CBM development ends. Springs that issue from the Wasatch sands into surface drainages may experience increased flows during the period that CBM produced water is recharging shallow aquifers.

The use of infiltration impoundments or flow-through stock reservoirs during surface discharge associated with CBM development could increase existing spring flows where a near-surface zone of low permeability intercepts the surface. This increase in spring flow would not occur if these water handling facilities are sited to minimize this potential effect. Avoidance of sites where a zone of low permeability intercepts the surface downhill or downgradient from an area where considerable infiltration of CBM-produced water is occurring would minimize the potential for shallow infiltrated water to increase the recharge or flow of existing springs.

Negligible infiltration would be anticipated where containment ponds or reservoirs constructed in upland areas would be used to handle CBM produced water. It is unlikely that existing spring flows would be affected near properly engineered and constructed containment impoundments.

6.5.2 Groundwater Discharge Areas

Groundwater has been discharging to the surface in many areas near the Powder River where the hydraulic head from the deep coal aquifer intercepts the surface and flow along the natural groundwater gradient is toward the river. A reduction in hydraulic head within the coal aquifer, projected to occur during CBM development under Alternative 1, likely would reduce groundwater discharge and base flows in surface drainages within the Powder River's drainage basin. Groundwater discharge likely would not recover until the hydraulic head in the coal aquifer recovers sufficiently after CBM development ends.

Negligible infiltration would be anticipated where containment ponds or reservoirs constructed in upland areas would be used to handle CBM-produced water. It is unlikely that new springs would develop or that shallow infiltrated water would resurface near properly engineered and constructed containment impoundments.

The use of infiltration impoundments or flow-through stock reservoirs during surface discharge associated with CBM development could cause new springs to develop where a near-surface zone of low permeability intercepts the surface. This increase in spring flow would not occur if these water handling facilities are sited to minimize this potential effect. Siting in accordance with applicable WDEQ and WSEO requirements and avoidance of sites where a zone of low permeability intercepts the surface downhill or downgradient from an area where considerable infiltration of CBM-produced water is occurring would minimize the potential for shallow infiltrated water to resurface.

The detailed model study for the LX Bar drainage (Chapter 9) focused on the potential contributions to surface flows from increased groundwater discharge associated with rising water tables that would result from infiltration ponds. This modeling study assumed that all CBM-produced water in the LX Bar drainage was discharged to infiltration impoundments. The model indicated that the resulting rise in groundwater levels within shallow Wasatch sands would occur regionally, up to 10 feet, and locally near the impoundments up to 50 feet. The net increase in surface water flows would be less than 0.1 cfs or 45 gpm.

The current water table may be shallow in many areas where infiltration impoundments could be constructed.Groundwater discharge may occur if infiltration causes the water table to rise above the surface. In these areas, the increase in water level may be exhibited as standing water in areas that did not previously display this condition or as wetland development, unless the percentage of CBM wells where produced water held in infiltration impoundments is carefully controlled. The effects of impoundment and infiltration of CBM-produced water would need to be analyzed on a site-specific basis to ensure that water table and groundwater discharge effects are carefully balanced or mitigated during CBM development.